APRIL 1950

Journal

VOL. 42 • NO. 4

AMERICAN WATER WORKS ASSOCIATION

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HOW WATER METERS *Save Water*

HERE are just a few examples of the actual water savings effected by meters in all types of towns and cities. These savings represent correction of leakage, careless waste or unauthorized use. In no case do they mean reducing the legitimate use of water. These figures speak for themselves – yet they only begin to tell the story.

For complete factual data, call on your Trident Representative.

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18% metered – Per capita consumption 130 gpd. Pop. 960,000.
100% metered – Per capita consumption 91 gpd. Pop. 1,440,000.

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Metered – Per capita consumption 60 gpd.

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10% metered – Per capita consumption 350 gpd.
100% metered – Per capita consumption 116 gpd.

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Metering cut consumption 16%, postponed $250,000 expenditure for additional water supply.

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Metered – Per capita consumption 63 gpd. Pop. 135,000.

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100% metering "reduced careless consumption so that no acute shortage occurred."

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RESULTS – Saving on domestic consumption (first year) approximately 60%. Universal Trident Metering revealed unaccounted for (wasted) water amounted to 25%, helped to reduce it to 14%, the overall saving making available additional 1 mgd, worth $29,200 per year. Investment in metering – $35,000; increased storage facilities for equivalent additional water supply would have cost many times that.

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TRIDENT WATER METER

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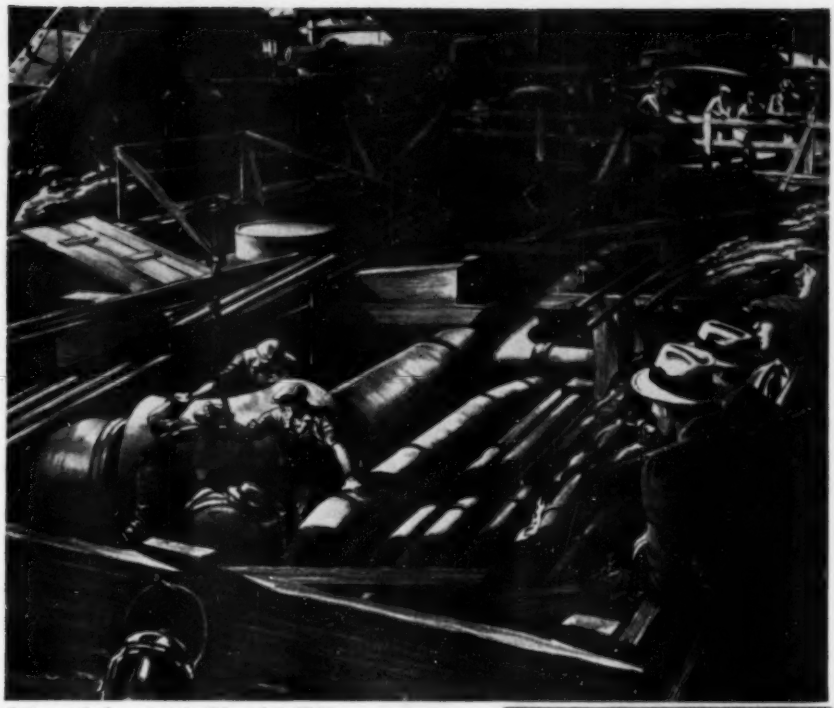

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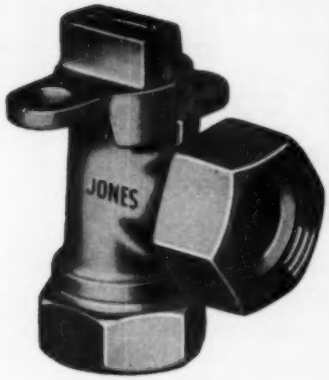

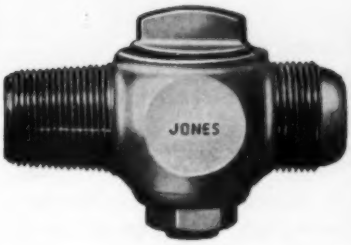

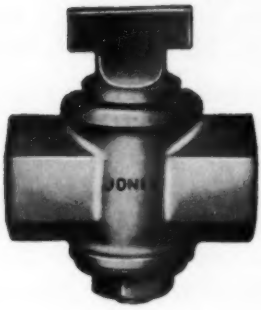

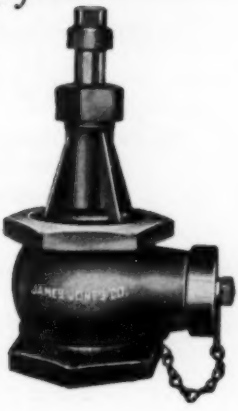

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Philadelphia, Pa.

May 21–26

Reservation forms have been mailed to all members, and all reservations will be cleared through the A.W.W.A. office. The hotels have agreed to accept no reservations for the 1950 Conference except as they are requested on the standard form prepared by the A.W.W.A.

Accommodations at Eleven Hotels

All Technical Sessions and Exhibits at Convention Hall

April 12–14—Illinois Section at LaSalle Hotel, Chicago. Secretary: Carl N. Brown, Western Sales Mgr., U.S. Pipe & Foundry Co., 122 S. Michigan Ave., Chicago 3, Ill.

13–14—Nebraska Section at Cornhusker Hotel, Lincoln. Secretary: J. W. Cramer, 922 Trust Bldg., Lincoln 8, Neb.

20–21—Kansas Section at Lamer Hotel, Salina. Secretary: H. W. Badley, Repr., Neptune Meter Co., 640 Highland St., Salina, Kan.

21—California Section. Regional spring meeting in Santa Cruz. Secretary: W. W. Aultman, Box 38, LaVerne, Calif.

21–22—Montana Section at Florence Hotel, Missoula. Secretary: Harvey W. Taylor, Montana State Board of Health, Helena, Mont.

26–28—Indiana Section at Purdue Univ., Lafayette. Secretary: C. H. Bechert, Dir., Div. of Water Resources, Ind. Dept. of Conservation, 445 N. Pennsylvania, Rm. 200, Indianapolis 4, Ind.

May 11–13—Pacific Northwest Section at Hotel Winthrop, Tacoma, Wash. Secretary: Oscar P. Newman, Boise Water Corp., Boise, Idaho.

June 29—New Jersey Section Clambake and Outing, Germania Park, Dover. Secretary, C. B. Tygert, Box 178, Newark 1, N.J.

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Why not submit your corrosion problems to our Contract Department? Write us today.

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Many water plant operators control tastes and odors *and* their customers tempers by constant small dosages of Aqua Nuchar Activated Carbon. This prevents a sudden taste or odor condition from getting out of control, since a relatively small increase in the amount of Aqua Nuchar will quickly restore the palatability of the water.

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Journal

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April 1950

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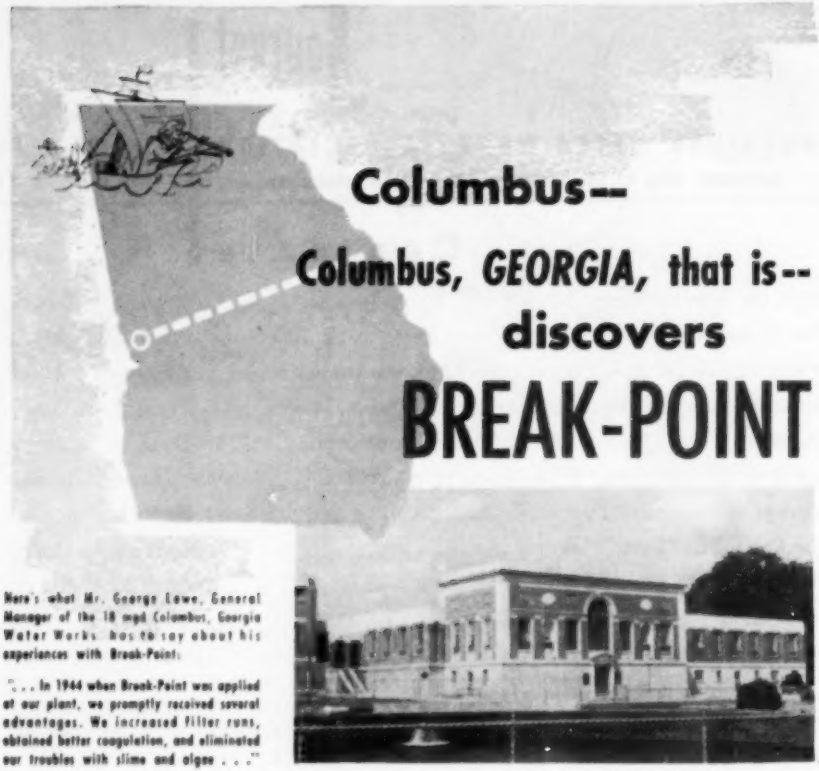

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AMERICAN WATER WORKS ASSOCIATION

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Rates for General Water Service

By Orville P. Deuel

A paper presented on Oct. 13, 1949, at the Wisconsin Section Meeting, Milwaukee, Wis., by Orville P. Deuel, Rate Analyst, State Public Service Commission, Madison, Wis.

A SOUND approach to determining a reasonable rate for water service is to base the price on the cost of furnishing the service. Such a price is practical for a commodity not sold in competition. A pricing policy based on cost has a historical basis as old as modern civilization. During the Middle Ages there was developed a theory of "just price," a price that covered all reasonable cost plus enough more to maintain the social status of the seller. Any price yielding a return much in excess of cost was regarded as exorbitant and subject to the penalty of church and state. Out of this background developed the concept of reasonable rates, as it is now known. Supreme Court Justice Hughes, discussing the question of specific freight rates for coal, said of them: "The outlays that exclusively pertain to a given class of traffic must be assigned to that class, and the other expenses must be fairly apportioned. When conclusions are based on cost, the entire cost must be taken into account." A limitation on the application of the cost theory of rate determination was set forth in *Smyth* v. *Ames* by the U.S. Supreme Court when it stated: "What the public is entitled to demand is that no more be exacted from it . . . than the services rendered . . . are reasonably worth."

Each municipal utility is entitled to earn, if possible, revenues sufficient to provide for reasonable operating expenses, depreciation expense, tax equivalent and profit, but the task of setting up proper rate schedules does not end there. The utility, in cooperation with the Wisconsin Public Service Commission should periodically check its rate structure to determine whether or not changes in population, changes in the use of service, expansion of the use of water or changes in the industrial or social life of the community have

rendered the existing rate schedule obsolete.

Although water rates differ from rates for service by other public utilities, there is a resemblance to exchange telephone service rates in the use of minimum charges or a service charge. There is also a similarity to electric rates in the customary use of a commodity or output charge, but there the similarity ends. Water rate schedules are comparatively few in number and simple in form and have a lack of uniformity not found in electric rates. These differences arise largely from the basic difference in the commodity sold and the customary uses made of it. The recently increased desire to use water for air conditioning and other cooling systems might have changed the water rate situation and resulted in a more complex rate structure had the new demand not coincided with an alarming drop in the level of ground waters in many parts of the state. Where an ample supply exists and the commodity can be used indiscriminately without danger to sound conservation of natural resources, water rates of a highly promotional type might be given consideration.

Rates for water service differ widely between communities for several reasons. The size of the utility has a direct effect on rates, because usually the larger it is, the lower the unit production costs. Size, in turn, depends on the location of the utility, because the service is by its nature limited to urban areas and it has not been found practicable in Wisconsin to establish water transmission mains connecting urban centers. A second cause of lack of uniformity in water rates is the natural variations in the source of the commodity. Purification and treatment needed and depth of wells all directly affect operating expenses and therefore rates. Problems of transmission vary widely between communities. Because the water utility is essentially local, and because most of its plant has a comparatively long life, the fixed charges will vary greatly with price levels existing at the time of any major capital improvement and rates will be affected for many years.

Allowable Expenses

The problem of reasonable rates based on costs leads to consideration of the matter of reasonable expenses and investment in plant. Because major capital expenditures by Wisconsin public utilities must be authorized by the public service commission, the determination of fixed charges related to investment is not usually difficult for the ratemaker. Furthermore, it can often be assumed that previously recorded operating expenses are indicative of future requirements. In general, courts and commissions have been quite insistent that costs employed as a standard of reasonableness refer to the usual expenses incurred under the reasonably efficient management of a going concern. The idea of allowable expenses was well stated by a federal judge in 1923: "To be allowable in a rate case, operating expenses must be reasonable. The utility should be permitted to earn the cost of operation and a fair return; but, in addition to a fair return, it is not entitled to earn whatever it may choose to spend. Its expense account is limited to the reasonable cost of efficient ordinary operation, to the exclusion of expenditures too large, or otherwise improper, unjust or unfair to its patrons, who must pay them, if provided for by higher rates."

Design of Rate

Assuming that reasonable costs have been determined and apportioned between the two major classes of service —namely, public fire protection and general service—there remains the problem of designing rates for general service.

Historically, many utilities furnished water service at a schedule of so-called flat rates. The simplest schedules were those which set up a uniform charge for residences and small commercial customers and specific tailored rates for large commercial and industrial customers. Such rate schedules frequently included an added charge for lawn-sprinkling privileges, and some were quite complicated.

Few persons concerned with water utility rate problems would argue for a return to the flat rate. The basic problem involving general service rates today is found in the form and design of rates for metered service. A two-part rate is in general use in Wisconsin. In the larger cities the rate structure usually consists of a schedule of service charges and another for output charges. In other communities, a combination minimum bill and output schedule is used in which the minimum bill includes the service charge plus the cost of water allowed for the minimum.

To design such a rate schedule, costs allocated to general service are first divided into capacity costs, direct expense, output costs and fixed charges. Capacity costs, direct expense and a portion of the fixed charges are used to determine the minimum bill or service charge.

Demand Costs

The Wisconsin Public Service Commission, in docket 2–U–677, sometimes referred to as the Milwaukee Water Works case, said:

> Engineering authorities of which we take judicial notice (such as *Kent's Mechanical Engineers' Handbook* [Ref. 1] and *Merriman's* [*American*] *Civil Engineers' Handbook* [Ref. 2]) and the reported experience of meter manufacturing companies indicated considerable variation in the theoretical capacities of service pipe and meters of different sizes. Actual demands are recognized to vary widely from theoretical demands. Nevertheless, if we assume a velocity of flow in service pipes of 9.8 fps., a ⅝-in. meter, according to one authority, has a potential demand of about 1.25 cfm.; whereas a 4-in. meter has a potential maximum demand of about 51.3 cfm. Even if the velocity of flow assumed is less, say 6.0 fps., a 4-in. meter would have an indicated or potential maximum demand of 31.4 cfm., which is many times that of a ⅝-in. meter.

The total theoretical demand, in cubic feet per minute, for general service can be readily determined from a tabulation of the number of meters of each size related to the theoretical demand per meter. This total, divided into the capacity costs assigned to general service plus directly assigned expenses and a portion of the assigned fixed charges, results in an indicated cost per cubic foot per minute of demand, which factor becomes the basis for determination of the readiness-to-serve charge.

From studies of the use of water service by various classes of customers, it has been concluded that residential users (usually with ⅝-in. meters) will impose the maximum demand on the system for lawn sprinkling during an early summer evening. It is usually true that commercial and industrial customers, as a group, will not place their

heaviest demand on the system during the evening hours. Consequently, it appears reasonable to adjust the demand costs assigned to larger meters to allow for the noncoincident demand of the group and for diversity of use of service among the larger consumers.

If costs assigned to demand or readiness to serve are recovered in the rates charged for water consumed, they are paid for by each customer in proportion to the volume of water purchased. Volume of water used, however, may have no direct relationship to the potential demand of a customer which the utility must be prepared to meet at all times. Assignment of demand costs on the basis of theoretical or potential demand results in a rate schedule which makes possible a lower average rate for good load factor customers and a higher average rate for poor load factor customers, thus being in agreement with proper rate design.

Output Costs

If, for historical or other reasons, it is not practical to recover all demand costs assigned to general service in the service charge or minimum bill schedule, the balance of such costs may be relegated to the output costs and recovered in the first few steps of the output or commodity part of the rate schedule.

The design of the output schedule will ordinarily be premised on the average cost per unit sold. It has usually been found desirable to employ a graduated schedule of output costs. The wisdom of such a schedule is evident when a portion of the demand cost has been included with the total amount to be recovered in the output schedule. A further basis for employing a graduated rate schedule is found in the operation of the principle of added cost. If only small quantities of water were sold, unit production costs would be high. Quantity sales are in large measure responsible for production volume, which is accompanied by lower unit costs. Another compelling reason for a graduated output schedule is found in the possibility of competition from privately owned wells of industrial customers. As a practical matter, it should be borne in mind that, until the point of diminishing return is reached, added pumping can result in profit if the selling price is slightly in excess of the sum of the pumping cost and incidental variable expenses.

There is little, if any, uniformity in the number of blocks in existing rate schedules and in the spread between the top and bottom blocks or the range of minimum bills or service charges. Examination of the rate files of twenty utilities of various sizes revealed that a six-block rate schedule was used by eight of them. Six schedules consisted of five blocks; four, of seven; and two, of eight blocks, minimum bill included. Among the twenty schedules, the greatest spread between the top and bottom block was 33¢ for 1,000 gal. and the smallest, 6¢. Eleven of the schedules quoted rates in terms of 100-cu.ft. units, with an average spread of 13¢ between the top and bottom block. The other nine quoted rates for each 1,000 gal. of water sold, with an average spread of 21¢ per 1,000 gal.

Demand charges for a ⅝-in. meter ranged from 50¢ to $4.25 a quarter, with an average of $2.25. The average amount of water included with the minimum bill was approximately 6,250 gal., or 830 cu.ft. each quarter.

When a schedule of output charges is to be designed, the average output cost per unit of water sold may be used as a tentative rate for a middle

block in the schedule. The range from top to bottom may be found by location of the bottom of the schedule at the point where price per unit of sales equals added pumping costs plus a small margin. Doubling the spread from the lowest unit cost to the average cost per unit gives an indicated rate schedule range. Arranging the blocks so that revenues will equal cost is a trial-and-error process.

The need for more than one schedule of general service rates to differentiate between classes of customers has been minimized by the effect of a two-part schedule with service charges proportional to demand and graduated output schedules.

Multiple Connections

The practice of including an additional demand charge when more than one unit of service is connected through one meter has increased in popularity. Although the basis for such a charge may be found in the theory of making rates commensurate with what the traffic will bear, a valid defense of the practice is provided by the fact that demand charges are based on the theoretical rate of flow, which is not necessarily the maximum. It appears that instantaneous demand would be greater in an apartment house than in a single-family residence, even if the meter size were identical for the two. A problem may result when the additional-unit charge is applied to an apartment house or office building with a comparatively large meter if the rate schedule is so designed that the demand charge approximates the assignable demand costs. One utility recently met the problem by filing the following rule:

> A charge of 75¢ will be applied for each additional unit of service on a ⅝-in. and ¾-in. meter. Where a larger-size service and meter have been installed (for domestic and small commercial use only), the following table will apply, indicating the number of additional units permissible before the charge for additional units will be applied: 1-in. meter, two additional units; 1¼-in. meter, three additional units; 1½-in. meter, five additional units; 2-in. meter, nine additional units; over 2 in., no additional charge for additional units.

Other Problems

A number of other difficulties often encountered in designing a water rate schedule are considered minor only because the revenues involved are small. Utilities frequently desire to charge a higher rate for suburban or rural service. The usual practice is to establish rates for such service by adding a fixed percentage (usually 25 per cent) to the service bill computed at the urban rate schedule. Water utilities often operate at less than the maximum allowable return as a matter of choice, in order to serve the citizens of the municipality that owns the system at the lowest possible rates. Usually there is no philanthropic inclination to extend the benefits to residents of a neighboring political unit, particularly where the neighbors are potential additions to the municipality.

A second reason for the higher charge is found in the usual lack of fire protection service revenues from neighboring rural areas, which means that general-service customers are deprived of the benefits of joint costs. An argument is sometimes advanced that greater distances from the center of the system should result in the assignment of higher unit costs.

Rates for service to the municipality are sometimes preferential, because, particularly in smaller communities, the time and place of municipal use may be

controlled to avoid peak demand periods. Frequently such service is furnished at or near the bottom step of the general-service output schedule.

Proper rates for seasonal service sometimes present a problem. The rate should vary with the design of the general-service rate schedule. A guiding principle would be that the customer should pay a year-round demand charge, particularly where the use is during the peak summer months.

Rates for building and construction and occasional use of service are varied. Where practicable, such service should be metered and metered-service rates applied. If metering is impracticable, such service may be covered in the rate schedule by a minimum permit charge. A third method of billing for building and construction work is to estimate the consumption of water on the basis of the size and type of construction.

Rates for unmetered private fire protection service have been the subject of much controversy. An examination of rates on file with the commission discloses that such rates vary from 100 to 12.5 per cent of the service charge applicable to metered service. It is sometimes argued that the existence of private fire protection service benefits the municipality as well as the customer. The argument may be well founded, but the reduction in the cost of furnishing public fire protection service would be limited to the possibility of a lower output cost, which is a comparatively insignificant part of the total cost. On the other hand, the customer benefits directly through a reduction in fire insurance premiums, which is a measure of the value of the service to him.

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Fire Protection Service Charges

By Preston A. Reynolds and George K. Hood

A paper presented on Oct. 13, 1949, at the Wisconsin Section Meeting, Milwaukee, Wis., by Preston A. Reynolds, Public Utility Rate Analyst, and George K. Hood, C.P.A.; both of George K. Hood, Madison, Wis.

THE term "fire protection service" designates the service which the water utility furnishes a community by having a reliable source of water supply, pumping equipment, storage facilities, and transmission and distribution mains and hydrants. This service should be adequate to supply the fire-fighting apparatus of the city, village or town with all the water it requires at any time and under conditions of peak demand by the general-service customers.

Most cities have provided, and are now maintaining at great expense, first-class fire departments and thoroughly equipped fire stations in many wards. To make a fire department effective, it needs, in addition to its equipment, an ample supply of water available at all times with adequate pressure for that equipment. Since the fire protection service is worthless if the water supply fails, the value of the service cannot be measured by the amount of water used or by comparing the service to that furnished large industrial users, as has sometimes been attempted. Nevertheless, because of misinformation or faulty reasoning, many aldermen and city officials consider that adequate charges for this service are exorbitant.

Fire protection service is not merely of individual benefit but is enjoyed in common by the citizens in general. In most of the arguments arising on this subject, the attempt is made by critics to split hairs between the "use" of the service and the "consumption of water."

A very irregular and ordinarily very infrequent use of water for fire protection service exists in most communities, whether they are small or large. When such use is necessary, however, the quantities of water required per minute are at times very large, and the service is of extreme importance.

The opinion of many officials seems to be that practically the same water system which now exists in their community would be required if no fire protection service were rendered at all. Conversely, however, if no general service were rendered, a water system practically identical with the existing system would be required for fire protection. It follows, therefore, on any fair basis of comparison, that when the two systems are combined some portion of the value of the water system other than the investment in hydrants is allocable to fire protection service. By combining the two systems in one, a decided economy is secured in the amount of the investment required, but for all of this saving to benefit one class of service alone would be discriminatory.

It appears clear that the public fire hydrants have no value for fire protection service unless they are connected to the distribution system. The latter is of no use unless it is filled with water and the pressure is maintained either by

elevated storage tanks or reservoirs or by pumping equipment. It seems reasonable and equitable, therefore, to allocate to public fire protection service on some definite basis a substantial portion of the fixed capital. Readiness to supply water under adequate pressure is a more important feature in this service than the actual amount of water used. The consensus of those who have studied this matter extensively seems to be that the charge for fire protection service is properly of the nature of a demand or capacity charge—that is, a charge for readiness and ability to serve—and has no particular relationship to the amount of water actually consumed for the purpose.

The charge for fire protection service is often referred to as a "hydrant rental." This term is misleading because the hydrant is only the opening through which water is taken if a fire occurs. It is obvious that the hydrants do not comprise all of the equipment and facilities of the water utility used and useful in fighting fires. On this "hydrant rental" basis, public fire protection costs consist only of the expense remaining after assigning to general service all the operating and fixed charges on pumping facilities and transmission and distribution mains, some of which, at least, are jointly used for both general and fire protection service.

Several factors prevalent in Wisconsin have made it imperative to establish reasonable and equitable fire protection service charges. Among these are: state regulation of rates and service for all classes of water utilities, both private and municipal; and statutory provision prohibiting free service and discrimination.

During the 40 years that the Wisconsin Public Utilities' Law has been effective, considerable progress has been made in devising a procedure for breaking down the cost of operating a water utility to assign an equitable part thereof to fire protection service. The various steps comprise:

1. A determination of the maximum demands which each major class of service makes on the utility.
2. A separation or breakdown of the water works property, used and useful, which can be said to have been built or installed for the purpose of being able to supply water at any time for fire protection service.
3. A determination of a rate base.
4. An estimate of the water used in fighting fires (usually a very small proportion of the total pumpage) plus the proportion of the lost and unaccounted-for water which is due to holding water in the system under pressure to make it available for fire protection.
5. A determination of normal utility operating expenses.
6. An apportionment of the direct normal operating expenses, plus allowances for fixed charges, such as depreciation, taxes and return on the rate base, among the major classes of service supplied, including fire protection service.

These six steps will be discussed in numerical order.

Determining Maximum Demand

The rate analyst has several sources from which to determine the fire demands: [1] data from the National Board of Fire Underwriters; [2] data from the Fire Insurance Rating Bureau; and [3] curves such as those developed by Freeman and by others in the field. Data for the larger cities are available from the fire underwriters, while considerable information on the smaller water utilities may be found in the rating bureau files.

The general-service demand can be ascertained from hourly and daily sta-

tion records, consideration of relative storage capacities and monthly and quarterly customer consumption data.

It is generally conceded that the capacity of a water system should be nearly, if not fully, sufficient to meet the combined maximum demands of both fire protection and general service.

To illustrate the mechanics of a cost allocation to determine fire protection service for communities of various sizes three examples will be given: a large city with many complications, a medium-size city and a small city.

A city with a population of 600,000 has an indicated demand, according to a National Board of Fire Underwriters report, of 12,000 gpm. for the first fire with an additional 8,000 gpm. for a second fire. The fire service pump requirements were determined for the low- and high-level service supplied by the utility:

Low service—12,000 gpm. required, equivalent to 17.28 mil.gal. on 24-hour basis; total pump capacity, 103 mil.gal.; ratio, 16.8 per cent; no reserve capacity, on account of special main system and special fire pump equipment.

High service—12,000 gpm. required, equivalent to 17.28 mil.gal.; to provide reserve, two pumps, each of preceding capacity, are assumed, so that total requirement is 34.56 mil.gal.; total pump capacity, 207 mil.gal.; ratio, 16.7 per cent.

In connection with the above, the formulas for Freeman's curves are:

$$\text{Max. } S = \frac{P}{5} + 10$$

$$\text{Min. } S = 1.7\sqrt{P} + 0.03\,P$$

in which S is the number of fire streams and P is the population in 1,000's.

A city with this population should have available a maximum of 130 fire streams and a minimum of 60, based on the formulas for Freeman's curves. At 200 gpm., these are equivalent to demands of 26,000 and 12,000 gpm., respectively. It may be noted that *Water Works Practice* (1) concludes that 12,000 gpm. should be available in cities of 200,000 population and over, with 2,000–8,000 gpm. available for a second fire. In the city under consideration, the fire demand will vary from 6.63 to about 10.6 per cent of the total demand.

A large city invariably maintains a great many portable pumpers. In the city used in this illustration, such equipment has an aggregate rated pumping capacity of 26,500 gpm. This apparatus pumps only from hydrants on the water department's mains.

An examination of the pumpage and consumption records will disclose the maximum hourly total, which, in this analysis, was equivalent to 243,688,000 gpd., or 169,000 gpm. To this figure is added an estimated fire protection service demand of 20,000 gpm., in order to apportion the total capacity or demand costs:

Demand	*gpm.*	*per cent*
General service	169,000	89.4
Fire protection	20,000	10.6
Total	189,000	100.0

It is not necessary at this time to discuss such facts as that the peak hour for residential users will not coincide with that for commercial and industrial customers. Only the 10.6 per cent of the demand costs allocable to fire protection service is of concern here.

In a community of about 90,000 population, consisting of a city and three adjacent villages and certain suburban territory, the maximum demand was 11,000 gpm., or 15,848,000 gpd. The peak rate occurred on July 9, 1948, between 6:45 and 7:00 P.M., and was

equivalent to a rate of 32,152,000 gpd. The demand for fire protection service represented 33 per cent of the total.

In a city of 1,500 population, the Fire Insurance Rating Bureau tests showed that the maximum available flow for fire protection service was 960 gpm. in the mercantile district and 620 in the residential. General service ran about 548 gpm., on the average. The fire protection ratio used was 50 per cent, or slightly under that indicated by actual tests made.

These examples emphasize the fact that, as a general rule, the demand percentages for fire protection increase as the population decreases.

Fixed-Capital Allocation

It seems improbable that unanimous agreement can be reached on the allocation of items of water works property to fire protection service. Consequently, a determination must be arrived at by careful study and the exercise of judgment as to what is fair.

A detailed apportionment for a water system with a reported book cost of $27,946,000 is presented here with the bases used, for those interested.

Land and buildings. The value of land and buildings might be apportioned on the basis of the estimated required capacities of pumps and equipment—which govern the size of the buildings and hence the area of the land on which they stand—allocable to each class. The first allocation might be between high-level and low-level service. In the example cited, 16.8 per cent is charged to fire in the low-level portion and 12.7 per cent in the high-level area.

Source of supply. Fixed costs for the source of supply were first apportioned between high and low service, on a peak demand basis: low-service fire protection, 21.7 per cent; high-service fire protection, 3.6 per cent suburban and 5.7 per cent urban. There being two pumping stations, the cost was apportioned between low and high service on the basis of the capacity of the pumps available for each service —30 per cent to low and 70 to high. Of the low-service portion, 16.8 per cent was charged to fire protection. The fire protection percentage of the high-service portion was 12.7, 3 per cent suburban and 9.7 per cent urban.

The cost of purification buildings and fixtures was assigned entirely to general service, although there was some argument that part of the storage capacity of the installation was useful for fire purposes. The cost of reservoirs, after being divided between high and low service, was further allocated in accordance with the demand percentages previously developed.

Boiler plant and power pumping equipment. Boiler plant and steam power pumping equipment costs were first divided between high- and low-level service, and then split on an assigned pump capacity basis. The cost of electric-power pumping equipment, used for high service only, was divided between the classes of service in this area, also on a pump capacity basis.

Mains. The cost of mains should have been apportioned between the high- and low-service areas, but there were no accurate data showing this division. As mains from 4 to 16 in. were tapped for general service, their footage, totaling 4,633,000, was used to assign $7,320,000 to urban general service. (The cost per foot was the minimum reported for the previous seventeen years, $1.58.) The balance of $9,300,000 was apportioned between general and fire service on a peak demand basis, 10.3 per cent being allocated to urban and 2.6 per cent to suburban fire protection. The hydrant cost was allocated entirely to urban fire pro-

tection service. Of the total historical cost as broken down, 10.78 per cent was allocated to urban fire protection service and 1.66 per cent to suburban.

In the medium-size city of 90,000 population, the use of a fire demand ratio of 33 per cent in apportioning the fixed capital (along with other factors, of course) resulted in a final property allocation of 27.8 per cent to fire protection. This percentage was used in allocating the fixed charges.

The total property, except for distribution mains, hydrants and purification equipment, as listed in the filed annual reports, was apportioned on the basis of the demands of the two major service classes. Costs of purification, services, meters and the like were allocated entirely to general service, whereas all hydrant costs were charged to fire.

In dealing with the distribution main costs, part of the hydrant cost which had been included therein was first removed. The original cost of about 234,000 ft. of 3-in. and 4-in. mains was allocated to general service. The rest of the main cost was split between feeder mains (40 per cent) and urban or local mains (60 per cent). The 40 per cent of feeder main cost was further subdivided—30 per cent, or slightly under the fire demand percentage, to metropolitan fire protection and 70 per cent to general service. The urban and local main cost (60 per cent) was divided 30:70 between urban fire protection and general service.

The amount assigned to metropolitan fire protection service was again broken down by allocating 93.75 per cent to urban fire service and 6.25 to suburban, the latter amount being spread among the villages and towns on a population basis in the absence of demand data. The suburban portion of the hydrant cost came to 5.7 per cent, based on the ratio of the cost of hydrants located outside the city to the total in the account. The suburban portion was broken down further on the basis of the number of hydrants owned by the city outside its corporate limits and the number jointly used.

These rather tedious details have been noted in order to show some of the complications which must be considered by the larger communities in arriving at an indication of reasonable percentages for allocating fixed charges (depreciation, taxes and return) to fire protection.

For the small city of 1,500 population, the use of the demand percentage previously noted, along with other factors, resulted in an overall allocation of 43.5 per cent of fixed capital to fire protection. This percentage was used in allocating the fixed charges.

In many Wisconsin communities, the cost of mains up to 6 in. are included in the assessment of the abutting property, and mains and hydrants are often installed on streets containing vacant property. It is believed that the method of estimating fire protection costs effects a more equitable adjustment of the interests of water users and taxpayers, as the citizen-owners of the municipal water utility should not be required to pay in their annual taxes a return or a tax charge on their own property.

All reported customer contributions have been excluded from the rate base for determining the return component of costs, as will be discussed later. It has been contended, however, that suburban customers who paid no main assessments were not entitled to any benefit from reduced interest charges on account of customer contributions.

In one rate case, the city officials argued that, because the special water main assessments exceeded the value of property assignable to fire protection service, this class of service should be

exempted from carrying any of the return. The regulatory commission failed to see any reasonableness in reducing the investment assignable to fire protection service merely because the amount contributed by abutting property owners and acquired through annexation without compensation happened to exceed the water works property value apportioned to this class of service. But in view of the fact that abutting property in the city had possibly paid for a part of the hydrant installation cost to the extent of a charge of about 28¢ per foot of main laid, the value of the property assigned to fire protection service was reduced by an amount equivalent to 13 per cent of the contributions for extensions. At the time this cost study was being made, it was reported that 24.7 per cent of the total assessed front footage of property in the city was vacant. The 87 per cent assigned to general service was therefore reallocated by charging 24.7 per cent to the vacant property. The resulting amount was added to the figure previously apportioned to fire protection service since the charge for the latter to the city presumably is paid from the general revenue of the city, the greater proportion of which is raised through taxes on real estate.

In the community with 90,000 population, contributions consisting of about 23 per cent of the total fixed capital of $3,411,000 came from assessments for mains, service contributions and a federal grant. All service contributions were allocated to general service. Main assessments were split on the basis of the total fixed-capital division, 25 per cent going to fire protection. Of the federal grant, 30 per cent went to fire and was then reallocated on the basis of total fixed capital assigned to urban fire protection, 94.8 per cent, and to suburban fire protection, 5.2 per cent.

Several apportionments made in this instance were the result of various suggestions by interested parties. In the final analyses, the total fixed capital assigned to fire protection service was between 25 and 28.4 per cent, the difference being due principally to the handling of contributions. In the small community, there were no contributions in aid of construction to be considered.

Rate Base Determination

The general practice followed in Wisconsin for most recent cost studies has been to start with the reported book value and add to it allowances for materials and supplies and working capital. From the total thus obtained is deducted the sum of the depreciation reserve and the contributions in aid of construction. (The latter, as previously noted, normally consists of special assessments for main construction.) The resulting figure is the rate base.

For a very large utility, supplying high-level and low-level service, with urban general and fire protection service in these districts as well as in certain suburban areas, the computations made to determine the rate base may be summarized as follows:

Total book cost		$27,946,000
Deduct:		
Estimated accrued depreciation	$3,096,000	
Contributions and special assessments	4,824,000	7,920,000
Balance		20,026,000
Add: Working capital and materials costs		1,000,000
RATE BASE		$21,026,000

Water Used in Fires

The water actually used in fighting fires is a very small percentage of the total pumpage. Usually from 3 to 5

per cent will cover the amount of water output expense chargeable to fire protection service.

Normal Operating Expense

As rates cannot be increased in Wisconsin without a formal investigation and order of the public service commission, to arrive at the cost of fire protection service normal operations must be considered. As a general rule, fire protection service rates are not fixed for one or two years, but for an indefinite period. The cost curve for all classes of service should show a more or less uniform upward trend as business normally increases and should not be fluctuating and erratic. All abnormal and unusual charges to operations, therefore, are usually smoothed out in arriving at basic data upon which to base charges for fire protection service.

The allocating and apportioning of the total cost of service fairly among the several classes of service inevitably has involved making certain assumptions which appear reasonable in the light of all the evidence. These detailed cost apportionments are guides to judgment and have been recognized as useful and necessary in reaching final conclusions.

The operating expenses are divided into demand, capacity or "ready-to-serve" costs, which depend upon the rate of use of water; variable or output costs, which depend upon the volume of water taken; and consumer costs, which depend on the number of customers connected and are independent of the amount of water used.

The demand or capacity expenses are allocated to fire protection service on the basis of proportionate demand. In the city of 90,000, 33 per cent fell to this class, while, in the larger city, 10.3 per cent went to urban fire protection and 2.6 to suburban.

Of the variable or output expenses, only from 3 to 5 per cent are chargeable to fire protection service. These are arbitrary figures intended to cover not only the output cost of the actual small quantity of water used in fighting fires but some additional out-of-pocket variable expenses incurred in getting water into the mains and holding these mains full under pressure. There is a constant loss of water through leaks in mains and hydrants and their branches that must be charged to each class of service.

No consumer expenses are allocated to fire protection service but such direct costs as maintenance of hydrants are.

The cost of operating the water utility also includes an allowance for depreciation, a tax equivalent and a profit component. The annual charge to operation for depreciation is usually based upon rates certified by the public service commission for the larger utilities and depends upon the estimated lives of various units. The composite rate used in cost studies has varied from 1.01 to over 1.5 per cent for small utilities.

The tax equivalent is normally arrived at by applying the local and school tax rates to a value based on the ratio of assessed to true value of comparable property. This ratio has varied from about 52 to 90 per cent of the book cost.

The allowable maximum return component has been 5.5 per cent of the rate base, but the city, as nominal owner of the municipal utility, has sometimes requested a much lower return, particularly on that portion of the fixed capital assigned to fire protection service.

When the allocation of costs is completed, a basic annual charge for fire protection service results, made up of standby costs and fixed charges depending directly on the required investment in plant and facilities neces-

sary to supply the service. Only a very small sum is included for variable (output) expenses. The per capita fire protection cost has ranged from less than $1.00 to more than $4.00, the variation being due principally to the amount of return component included.

Cost per Hydrant

Many appear to believe that the cost assigned to fire protection service should be divided by the number of hydrants in use, to get a cost per hydrant. Such a computation could result in a charge of $40 to $100 or more per hydrant. If, however, an additional block, or even several blocks, of mains are laid and hydrants installed, to add $40 for each hydrant placed might be excessive. An example will illustrate this point:

At the time the rate study was in progress in the large city previously mentioned, a 6-in. main cost $1.76 per foot to lay. With 6.63 per cent of the investment in mains allocable to fire protection service, plus an allowance of approximately 8.3 per cent for taxes, depreciation and return, the fixed charges per lineal foot of 6-in. main laid would approximate 1¢. Hydrants with pumper connections cost, in place (including the stub), about $200, and, with the same 8.3 per cent for fixed charges, there would be an additional charge of $16.60 for each hydrant placed. The laying of 1,200 ft. of main and the placing of three hydrants on this basis would add a $12.00 additional charge on main footage and $49.80 for hydrants.

Other Considerations

It should be noted that the addition of new pumps, sources of supply, elevated storage and other facilities might so affect the portion of fixed capital allocable to fire protection service as to necessitate reanalyzing the costs.

In some of the small communities, 6-in. mains now cost as much as $3.00 per foot in place. With 50 per cent of this cost assigned to fire protection service, or $1.50 per foot, the annual carrying charges for depreciation, tax equivalent and profit component alone will equal about 12.4¢ per lineal foot (depreciation, 0.67 per cent; taxes, 2.3; return, 5.5). The addition of some maintenance costs to the above figures results in charges of 13¢ or more per lineal foot.

It is often argued that the views of the "management" of a utility may be entitled to some consideration in fixing the charge to be made for fire protection service. Too often, however, the management is influenced by the pressure from city officials to hold the annual charge for fire protection service down irrespective of any cost indication. Some officials have arbitrarily, unfairly and unreasonably insisted on their judgment being accepted, when there was no detailed evidence presented to back up their very low estimate of the value of the service.

It is believed the bases developed and followed by the regulatory commission in determining rates have helped materially in putting municipally owned utilities on a sound operating basis whereby each one charges for all the service rendered. The attempt is being made to have water utilities operate on a business basis, but utilities cannot do so unless reasonable and equitable rates are established for each class of service.

Reference

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Water Supply for Fire Protection in Growing Municipalities

By Kenneth J. Carl

A paper presented on Oct. 25, 1949, at the Virginia Section Meeting, Roanoke, Va., by Kenneth J. Carl, Engr., National Board of Fire Underwriters, New York.

THE first step in providing an adequate fire protection supply is to determine the fire flow requirements in the district considered. These depend upon the construction, type, size, spacing and arrangement of the buildings which may become involved in a fire. When considered from the standpoint of municipal protection, fire flow is generally understood to be the rate of flow required for delivering water from the distribution system to the fire department pumpers. The residual pressure regarded as satisfactory for such delivery is 20 psi., and that figure will be assumed whenever fire flow is mentioned hereafter.

In the average built-up residential area, consisting of two-story one-family residences of moderate size which have noncombustible roof coverings and are spaced approximately 15 ft. apart, 1,500–2,000 gpm. would be required. If the buildings are only one story high, the required rate can be reduced to 1,000 gpm. In areas where only a portion of the lots are built upon, these rates may be reduced to 1,000 and 500 gpm., respectively, if the buildings are more than 30 ft. apart. When the arrangement and character of the blocks is such that additional dwellings can be erected upon the intervening lots, however, it is better practice to provide for the higher rates. In districts where the residences are larger and 2½–3 stories high, up to 3,000 gpm. may be necessary.

In apartment house areas, there is considerable variation in the rates which may be necessary. In the modern type of garden apartment development, with buildings usually two stories in height, 2,000–2,500 gpm. would be required. In the usual type of apartment house district, with buildings varying from three to five stories, the required rates range from 3,000 to 6,000 gpm.

Typical minor mercantile areas of attached one- and two-story buildings generally require 2,500–3,000 gpm. In newly developed areas, the mercantile buildings are usually only one story high, which often may permit a reduction in required fire flow to 2,000 gpm. In many such districts, however, there are one or two stores of exceptionally large area which would require greater quantities of water. In order to fight a fire in some modern supermarkets effectively, taking into consideration the large amounts of material usually stored in the basement or in areas not accessible to the public, rates as high as 3,500 gpm. might be needed.

The requirements for industrial areas are subject to such great variation that a general discussion of them is most

difficult. Such areas can vary from a few small, scattered plants to a heavily congested mill district or a large single plant covering many acres. Requirements can be as high as 10,000 gpm. There has been a tendency in recent years to locate new plants in the outlying districts of municipalities and sometimes beyond the city limits. In most such instances, the municipal water supply available for fire protection has been found to be inadequate. Frequently an individual plant will be provided with a private fire protection system equipped with hydrants available for fire department use. Where such protection is furnished and is well maintained, the water available from private systems may be entirely sufficient for the individual plant or may reduce considerably the fire flow which must be provided from the municipal system.

One method, described by A. C. Hutson (1), for estimating the fire flow requirement for an individual industrial building takes into account the area, height, exposure, construction and contents of the building; the extent of private protection in the form of automatic sprinklers, standpipes, automatic fire-detecting systems and special protective equipment for hazardous processes; and the size of the fire department. This method gives reasonable results for individual structures, and, in areas or plants consisting of numerous buildings, the figures obtained for each of the more important ones, when considered together with the general arrangement, should make possible a reasonable estimate of the fire flow.

The preceding statements on fire flow requirements are general and apply to average communities. Therefore, they should be considered not as hard and fast rules, but rather as guides in determining the fire flow necessary in any given area. The water supply engineer can frequently obtain helpful information on fire flow requirements from the chief of the fire department. He is responsible for the use of the water available on the fire grounds and should be in a position to offer some sound, practical advice.

New areas to be supplied fall into two general classifications: those which can be fed directly from the existing service or services and those which require additional pumping. If the area has the same range of elevations as the existing distribution system, it will be necessary only to extend mains of proper size into it and sometimes to provide storage within or near the area. In making such extensions, a definite plan should be laid out after an analysis of the growth that is likely to take place in the area under consideration. The preliminary studies should include a flow test or series of tests on the existing mains which will feed the new lines to be laid. Such tests will indicate whether or not the existing mains can supply the domestic and fire requirements for the new area and will also provide a portion of the data necessary to determine the sizes of the principal lines to be laid in the new area.

Sample Calculations

As an illustration, assume that a new, 500-home residential district with an area of 100 acres is to be developed; that the maximum fire flow required will be 1,500 gpm.; and that the area is beyond the existing distribution system but at approximately the same elevation. With consumption at the maximum daily rate, the results of a flow test on the distribution system in the vicinity of the point from which the new area will be supplied indicate that, for a discharge of 1,100 gpm., the pressure dropped from 59 to 49 psi. Assuming a maximum daily consumption rate of

200 gpm. for the new area, a total of 1,700 gpm. (the maximum daily consumption rate of 200 gpm. plus a fire flow of 1,500 gpm.) must be delivered. In order to determine the residual pressure at which 1,700 gpm. can be delivered at the point where the test was conducted, use is made of the fact that, for flow in pipes, the drop in pressure varies approximately as the square of the discharge. Expressed in symbols: $P_1 \div P_2 = Q_1^2 \div Q_2^2$, in which Q_1 represents the discharge in gallons per minute, P_1 is the drop in pressure during the test, Q_2 is the desired discharge and P_2 is the drop in pressure necessary to produce it. Substituting in the example under discussion and solving for P_2: $P_2 = 10 \times (1{,}700)^2 \div (1{,}100)^2 = 24$ psi. This result indicates that, with 1,700 gpm. flowing, the pressure at the proposed point of takeoff would drop from 59 to 35 psi. Since, for satisfactory supply to fire department pumpers, the fire flow should be available at 20 psi., the friction loss in the mains of the new area cannot exceed 15 psi. (35 minus 20) for a delivery of 1,700 gpm. to any point in the area. This requirement will determine the minimum sizes of the mains in the new section.

The actual choice of the mains to feed the area depends upon a number of features which may vary considerably, but, to continue the illustration, assume that a single main extends from the existing system for 500 ft. and then feeds four mains which branch out and extend through the area approximately 2,500 ft. as parallel, interconnected lines. It will be found that these conditions could be satisfied by a 12-in. main extending 500 ft. and then supplying two 8-in. and two 6-in. mains, with interconnections in the cross streets about 800 ft. apart. The required 1,700 gpm. could be delivered to the end of the district with a friction loss of 14.3 psi., or 0.7 less than the allowable loss of 15 psi. Actually the 200-gpm. domestic consumption would not all have to be delivered to the end of the district, since most of it would be taken off en route, but its inclusion is on the side of safety, and an attempt to reduce it progressively would not result in any practical decrease in main size in this illustration. Where consumption is a larger factor in determining main sizes, as in a manufacturing area, such progressive reductions should be made.

Although the layout selected in the above illustration would provide adequate protection, it would not be reliable, because a break in the single 12-in. line or any repair which required the line to be shut down would leave the area without water. This unreliability could be eliminated by extending another line from the existing distribution system into the area or by providing storage within it. Either of these installations would probably result in changes in the sizes and arrangement of mains originally considered.

Storage

Frequently a flow test on the existing distribution system will show that the quantity available is insufficient to provide for consumption and fire flow in the new area. Such would be the situation if the flow test in the preceding illustration had indicated a drop in pressure from 59 to 22 psi. for a flow of 800 gpm. Under these circumstances, it would be necessary to strengthen the existing system by installing additional main capacity or by providing storage either in the general vicinity of the site at which the test was made or in the new area. Such storage should be connected to the system by a main not smaller than 12 in.

The installation of storage in new areas, particularly if they are large, is an effective method of providing a substantial portion of the required fire flow. The storage may be in elevated tanks or in ground reservoirs with pumps delivering into the distribution system. Local conditions will usually determine which of these types to use. Elevated storage has the advantage of being available at the system pressure at all times, not being dependent upon pumps started manually or automatically. Where pressures are greater than about 60 psi., requiring high towers in a flat area, or where elevated storage tanks are not desired because of the character of the neighborhood, ground storage reservoirs with pumps discharging into the distribution system have proved satisfactory. In such installations, not less than two pumps, with a reliable electric power supply or standby engines, should be provided.

If the new areas to be supplied are at a lower elevation than the existing distribution system, regulating valves are frequently used on the lines to the new area to prevent excessive pressures. When this type of valve is installed, a bypass should always be provided and the vault in which the valve is located should have good drainage. Maintenance is important for the proper functioning of pressure-regulating valves. Municipal fire protection surveys often disclose regulating valves which are not operating satisfactorily. To assure proper operation at all times, these valves should be inspected weekly, a pressure reading being taken on the high and low sides, and tests should be made at regular intervals by opening one or two hydrants on the low side and observing the operation of the valve.

When the elevations in the new area are higher than can be satisfactorily served by the existing distribution system, a separate service capable of supplying the area at suitable pressures must be provided. Practically all such high services are supplied by pumping from the existing system. Where storage in the form of a reservoir or large elevated tank is available on a low service, the best location for the high-service pumping station is at the storage site, so that a good suction supply will be assured. Such a location has, among others, two distinct advantages over a location where the suction supply must be taken directly from the mains of the low service at a point remote from storage. In the first place, the effect of the operation of the high-service pumps on the pressures in the low service does not have to be considered, since the suction supply will be from storage; and, second, a break or accident requiring a shutdown on the low service will not cut off the suction supply for the high-service pumps. The latter consideration was recently brought to the attention of water supply engineers in connection with breaks in large mains in two cities. In each instance, the reduction in the supply to the low service caused by a break diminished pressures and supply in the vicinity of at least one high-service booster station to such an extent that the station was shut down. The services affected in these cities were, however, provided with elevated storage, which was of great value, although eventually some areas were without water.

Elevated storage should be provided on all high services supplied by pumping stations. From the fire protection standpoint, the storage can be used to furnish a portion of the required flow and it also offers a certain amount of reliability, as it assures some supply in the event of a pump, power or suction

supply failure. From the operational standpoint, elevated storage enables more uniform pressures to be maintained and more uniform pumping rates to be employed; it also provides a cushion against surges. Storage capacity depends upon local conditions, but, as a general rule, the minimum recommended for municipal use is 200,000 gal.

Booster Stations

Although it has been previously pointed out that the best location for a high-service pumping station is near low-service storage, there are many areas which must be supplied by a booster station taking suction directly from the low-service mains. The first step in considering a high service supplied in this manner is to ascertain whether or not the low-service distribution system can supply the station without serious reductions in pressure. This information can be obtained by making a flow test at or near the proposed booster station site and by determining, as indicated above, the residual pressure at which the quantity to be supplied by the station can be delivered. The quantity required will be the fire flow plus the maximum daily consumption, less the amount which can be delivered from the proposed elevated storage for the duration of a serious fire. If the results of the test indicate that the residual pressure, when delivering the required quantity, is less than that which the city has established as the minimum for the low service, additional main capacity will be needed in the low service to supply the booster station.

Because booster stations are usually required near the edge of the low-service distribution system, a strengthening of the latter is usually necessary. It can generally be accomplished by extending a main of sufficient capacity from one of the large arteries of the low service to the booster station. Recent fire protection surveys in several municipalities have revealed that little attention was given to the effect which booster stations would have upon pressures in the service from which the suction supply was to be taken. As a result, the pressures in the areas surrounding some of these stations are seriously affected whenever the booster station is operating.

The pumping stations should be of noncombustible material and well separated from other buildings. In some of the smaller stations, there will be separate pumps for domestic and fire use, since the two demands differ widely, but, in the larger stations, the pumps will be for either type of service. Sufficient pumps should be provided to deliver, in connection with the elevated storage provided, the maximum daily consumption rate plus the fire flow. In addition, a certain amount of reserve capacity should be installed.

The degree of reliability of pumping capacity depends a great deal upon the size and importance of the station under consideration. For principal stations, sufficient reserve capacity should be provided so that the required delivery can be made with the two largest units out of service; in the smaller stations, the same requirement should be met with the largest unit out of service. The power supply must be reliably arranged, or standby engines will be needed. Here again the importance of the station has a significant bearing on the degree of reliability required. For the larger stations, either duplicate power lines and appurtenances should be provided or sufficient standby engines installed so that the required delivery will be available in the event of a power failure. In arranging suction

and discharge piping, care should be taken to see that a break in a main or the repair of a valve will have a minimum effect.

Valves and Hydrants

Adjoining services in a distribution system are usually separated by closed valves, the location of which should be carefully marked on department records. This procedure is important because, in areas where the low service may be weak, an additional emergency supply can frequently be obtained from the high service by opening a valve at the service limit. Although the quantity available in this manner may not be large, it may be enough for several hose streams during a fire and can become an important factor in its control. In some cities where there is not too great a difference in elevation between the high and low service, check valves are used instead of closed gate valves on some or all mains extending between the services. This practice enables a small emergency supply at low pressure to be automatically delivered from the low service into the high service through the check valves when pressures are seriously reduced in the high service. When this arrangement is used, normally closed bypasses should be provided around the check valves to permit delivery from the high into the low service if necessary.

Even though the distribution system and the supply works feeding it are well designed and of adequate capacity, unless hydrants of proper type are available in sufficient number, the fire department will be handicapped in its operations. All hydrants should have at least two 2½- and one 4½-in. outlet and should meet A.W.W.A. specifications (*2*). The distribution of hydrants depends upon the fire flow required and, therefore, upon the character of the district. In typical residential districts, a simple rule to follow is to install a hydrant at each corner and an intermediate hydrant in blocks longer than 500 ft. For large apartment houses and in mercantile and industrial districts, additional hydrants are needed to deliver the greater fire flow required. Two, three or four hydrants at intersections and several at intermediate locations will frequently be found in larger cities, the arrangement depending a good deal on the size and shape of the blocks. All hydrants should be equipped with a gate valve in the branch connection, and sufficient valves should be installed on the distribution system so that the number of hydrants removed from service by a shutdown for repairs is held to a minimum. The valve spacing recommended by the National Board of Fire Underwriters is a maximum of 800 ft. in residential districts and 500 ft. in high-value districts.

Each new area which develops within a city or is acquired by it presents novel problems to the engineer in charge of the water supply system. The problem of providing adequate fire protection must be treated on an individual basis and frequently taxes the ingenuity of the best water supply engineers. It is hoped that the general principles, suggestions and information presented in this paper will be of some value in leading to practical solutions.

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Direct-Reading Electric Analyzer for Pipeline Networks

By Malcolm S. McIlroy

A contribution to the Journal by Malcolm S. McIlroy, Prof. of Elec. Eng., Cornell Univ., Ithaca, N.Y.

STUDIES of flow and pressure distributions in complex pipeline networks have often been hindered by the tedious computations required in conducting them. The direct electrical-analogy method of pipeline network analysis described in this paper eliminates all calculations beyond a simple change of scale. The method may be used either to evaluate flows and head losses for all pipelines in a network or to determine, from a single measurement, the value of total head loss between any two points in the network. Since the method is rapid and flexible, it permits comparisons of performance to be made easily among alternate plans proposed for extensions to or improvements in the pipeline network and its sources of supply.

The advantages of the direct electrical-analogy method can be understood by comparing it with the two general procedures now used. One procedure is to compute the values of head losses and flow rates by trial and error, using either of two schemes. For large networks, the relaxation method may be employed (1, 2), but the necessary repetitive work often discourages its use. For small networks, the linear approximation method (3) saves time compared with the relaxation method, but it also requires considerable calculation. The other general procedure is to evaluate the flows and head losses from readings of instruments connected to an electric circuit which simulates the pipeline network. In the methods of analysis now employing electric circuits (4–6), ordinary linear resistors represent the pipelines. Since the linear volt-ampere characteristic of an ordinary resistor is very different from the nonlinear head loss–flow characteristic of a pipeline, the first settings of the linear resistors give only preliminary values of currents or voltages. These values must be recorded for many or all resistors in the network, even though the purpose of the analysis may be simply to determine one or two values of total head loss across several pipelines. To find the desired final values of flow rates or head losses requires either a subsequent trial-and-error procedure, or the computation of corrections applying to all pertinent pipelines. The work involved in recording the preliminary values and in computing corrections is a disadvantage of previous electrical-analogy methods of analysis.

In contrast, the only readings taken in the direct electrical-analogy method, for an analysis to which the Hazen-Williams formula applies, are the final required values of flow rates and head

losses. No intermediate trial values, computations of corrections or readjustments of resistors based on results of successive approximations are involved. Even if greater refinement, in accordance with Darcy's law, is required, only a few preliminary readings of flow rates need be made, and a few resistors replaced, before final readings are taken.

In the direct electrical-analogy method, each pipeline is represented by a special nonlinear resistor, instead of a linear resistor as in previous methods. Each nonlinear resistor consists of a tungsten filament mounted in an evacuated glass bulb. The voltage across this filament varies with the current through it as friction head loss varies with flow rate in the pipeline it represents. A set of these resistors is interconnected according to the plan of the pipeline network. Given conditions of fluid supply to and discharge from the network are then simulated by operating the electric circuit in such a manner that controllable electric quantities are proportional to the known hydraulic quantities which they represent. When the circuit is in operation, the brightness of the incandescent filaments of the resistors directs the attention of the person conducting the analysis to the pipelines which have the largest head losses. Values of head losses and flow rates are read directly from special scales mounted on electric instruments. Direct analyses of networks of any degree of complexity and of almost any magnitude can be conducted, subject to a cumulative error in total head loss of the order of 3 per cent.

Although the electrical-analogy method may be used in studying networks containing various liquids or gases, this discussion is limited to its application in the field of water distribution. The basic analogies are stated, and a pipeline network analyzer is described. Representation of the nonlinear relation between head loss and flow in a pipeline by means of the special resistors is explained. The procedure of an analysis is then illustrated by a practical example. Detailed results of this analysis, showing a method of evaluating accuracy, are tabulated.

General Principles

Hydraulic and Electrical Analogies

The direct electrical-analogy method of pipeline network analysis depends upon four basic analogies, plus a fifth which results from the special characteristics of the nonlinear resistors used. The first basic analogy is that current in an electric circuit behaves in a manner similar to the flow of fluid in a pipe. Electric current is measured by inserting an ammeter in series with the conductor carrying the current, just as the rate of flow in a pipe is indicated by a flowmeter element placed in the fluid stream.

The second analogy relates voltage to friction head loss. The passage of electric current through a resistor is accompanied by a drop in voltage which is similar to the loss of head caused by the friction of water flowing in a pipe. This voltage across a resistor may be measured by a voltmeter connected across its terminals, just as head loss along a pipeline may be measured by a differential-pressure gage connected by tubing to the ends of the pipeline.

The third analogy concerns the law of balanced fluid flow at the junctions of a network, as illustrated by the pipeline network (Fig. 1a) and the analogous electric circuit (Fig. 1b). In the pipeline network, the total flow approaching any junction equals the total flow leaving it. For example, the flows, Q, are restricted by the relations $Q_1 = Q_2 + Q_4$ and $Q_2 + Q_3 = Q_5$. Since the sum of the currents approaching a terminal in an electric circuit equals the sum of the currents leaving it, the third condition necessary for a complete analogy is satisfied. Thus the currents, I, in Fig. 1b are related by the expressions $I_1 = I_2 + I_4$ and $I_2 + I_3 = I_5$, which are the electrical analogs of the corresponding flow equations for the pipeline network.

The fourth analogy concerns head losses in a network. The sum of clockwise head losses around any pipeline loop equals the sum of counterclockwise head losses. The heads, H, in Fig. 1a satisfy the expression $H' + H_1 + H_2 = H_3$. Likewise, the sum of the clockwise voltage drops bounding any loop in an electric circuit equals the sum of the counterclockwise voltage drops. The voltage drops, V, in Fig. 1b are governed by the relation $V' + V_1 + V_2 = V_3$, which is the electrical analog of the corresponding equation for head losses in Fig. 1a.

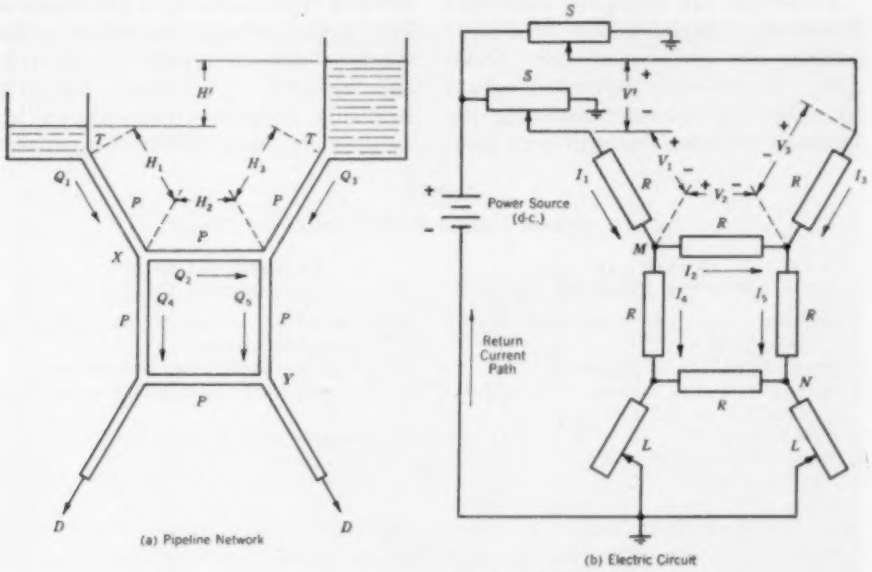

FIG. 1. Pipeline Network and Analogous Electric Circuit

An important fifth requirement must be fulfilled in order to obtain direct solutions from an electric circuit without a trial-and-error procedure. The friction head loss in a pipeline varies nearly as the square of the flow rate. Hence, an ordinary resistor, the voltage across which is proportional to the current through it, cannot represent any significant range of the operating characteristics of a pipeline. In the direct elec-

trical-analogy method, special resistors, designed so that the voltage varies nearly as the square of the current, satisfy the fifth condition. When these resistors are used, all quantities in Fig. 1a are represented by proportional quantities in Fig. 1b, as listed in Table 1.

Pipeline Network Analyzer

To use the five analogous conditions effectively, a device known as a pipeline network analyzer has been developed. It provides convenient means for mounting and interconnecting the nonlinear resistors that represent pipelines, for controlling source and load currents, and for measuring voltages and currents. Figure 2 is a photograph of the pipeline network analyzer located at the College of Engineering of Cornell University. This test model, the principal components of which were supplied by established manufacturers, provides space for mounting equipment analogous to a network of 127 pipelines but is initially fitted to represent 67 pipelines. Four sources and ten loads may be simulated. Future models can be constructed with increased capacity, to accommodate studies involving almost any number of sources, pipelines and loads.

Power may be supplied to the analyzer from any source of steady direct voltage, such as a storage battery, motor-generator set, rectifier, or d-c. distribution system. Manually adjustable rheostats, S in Fig. 1b, maintain the desired differences of source voltages which correspond to known differences of head between any pair of sources. Each discharge from the pipeline network is represented by a demountable load device selected according to the range of current needed to represent the discharge. The device may be a manually adjustable rheostat, an adjustable electronic circuit or a current-regulating ballast lamp. Ballast lamps, which semiautomatically hold the load current within desired limits, are used in the Cornell analyzer.

The nonlinear resistors which simulate pipelines are suspended vertically from sockets beneath the two horizontal panels representing the distribution network. These panels are permanently wired in a grid composed of squares analogous to pipeline loops, as indicated in Fig. 3. The permanent grid pattern minimizes the number of temporary connections which must be set up for an analysis. Changes in the basic grid pattern are made by inserting short-circuiting plugs in resistor sock-

TABLE 1

Analogies Between Pipeline Network and Electric Circuit

Quantity in Pipeline Network	Proportional Quantity in Electric Circuit
1. Difference in head H' maintained between two sources	1. Difference in voltage V' maintained between two sources
2. Friction head loss in pipeline P	2. Voltage across corresponding resistor R
3. Friction head loss between any two junctions, XY	3. Voltage between corresponding terminals MN
4. Flow in pipeline P	4. Current in corresponding resistor R
5. Flow at discharge D	5. Current in load device L
6. Flow from tank T	6. Current maintained at source S

ets, by leaving sockets empty or by connecting flexible jumpers between pairs of jacks located at the junctions of the network wiring.

Each power source, nonlinear-resistor socket and load device is connected in series with a current-diverting jack, which normally has no effect in the network. To measure the current in any circuit element, the analyzer operator inserts a special plug in the associated jack. This plug transfers the current through flexible jumpers to the master ammeter, which indicates both magnitude and direction of flow in the corresponding pipeline. To measure head loss, the operator connects the master voltmeter to the appropriate pair of junctions in the electric circuit. Although the master ammeter and voltmeter are actuated electrically, special demountable scales give direct readings in terms of flow rates and head losses.

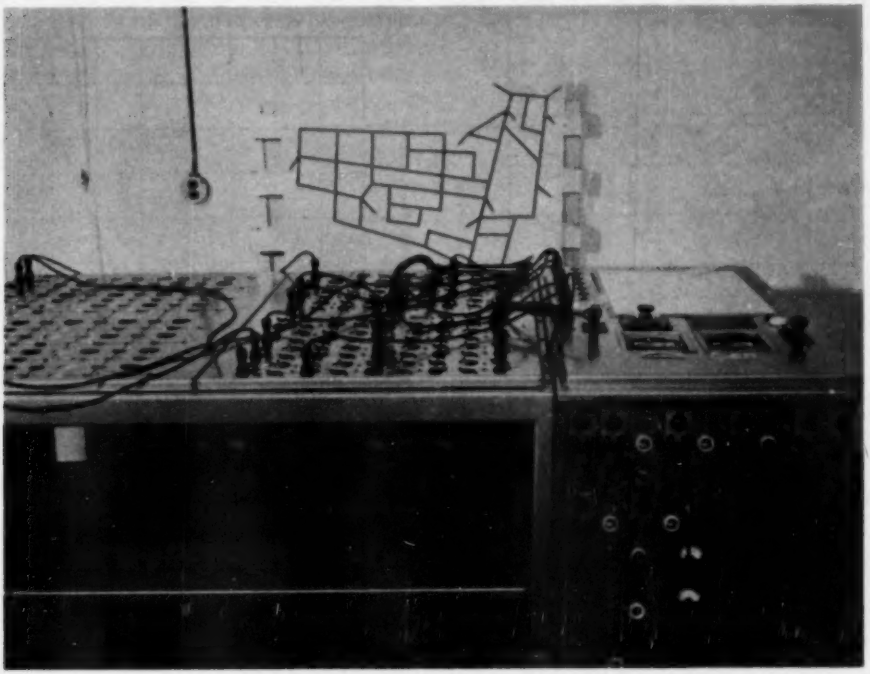

FIG. 2. Pipeline Network Analyzer

Representation of Performance Characteristics

Since the direct electrical-analogy method of network analysis depends largely upon the performance of the resistors used to represent pipelines, a discussion of their design and operating characteristics is necessary. The relation between head loss and flow rate in a pipeline may be stated in several ways, among which are those postulated by Darcy's law, the Chezy formula, and the Hazen-Williams for-

mula. For studies of water distribution systems, the last is often used. This formula may be expressed as a simple exponential relation of the form:

$$H = k_p Q^{1.85} \quad \ldots\ldots\ldots (1)$$

in which H is the head loss; k_p is a constant, called the "head loss coefficient" of a pipeline, with a value depending on the length, diameter and conditions of the pipeline; and Q is the flow rate.

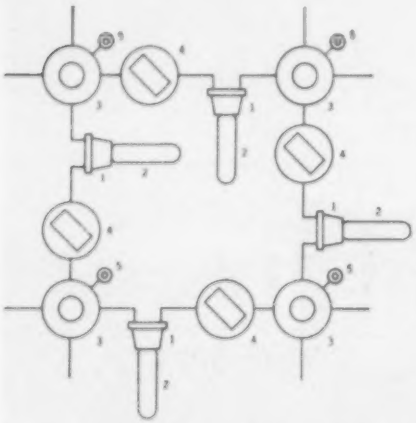

FIG. 3. Analyzer Representation of Network Loop *

* Key:
1—nonlinear resistor socket
2—nonlinear resistor
3—junction jack
4—current-diverting jack
5—voltage-measuring jack

The electrical analog to Eq. 1, which expresses the desired relation between the voltage, V, across a resistor and the current, I, through it, is:

$$V = kI^{1.85} \quad \ldots\ldots\ldots (2)$$

in which the constant, k, analogous to the head loss coefficient of a pipeline, is called the "coefficient" of the resistor.

Since the voltage in Eq. 2 does not vary in proportion to the current, the equation is nonlinear and must be represented in an electric circuit by a nonlinear resistor. The required nonlinear volt-ampere characteristic differs greatly from the characteristic of ordinary linear resistors that perform according to Ohm's law, $V = RI$, in which the resistance, R, is a constant. This difference is shown in the graphs of Fig. 4, where curve A portrays the desired characteristic of a

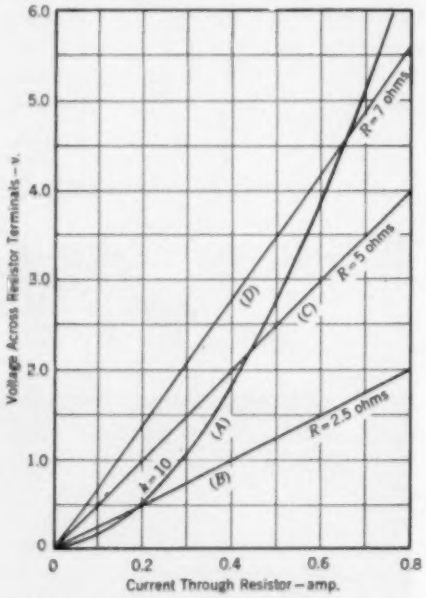

FIG. 4. Volt-Ampere Characteristics

nonlinear resistor having a coefficient, k, of 10. The resistor should hold the desired relation between voltage and current throughout its normal range of operation. The straight lines, B, C and D, illustrate the relation between voltage and current maintained by ordinary linear resistors having resistances of 2.5, 5 and 7 ohms, respectively. As each linear resistor can relate the voltage and current correctly only at the

intersection with the nonlinear characteristic, linear resistors cannot be used to provide direct solutions to problems in pipeline network analysis.

The nonlinear resistors used in the pipeline network analyzer are designed to perform in accordance with Eq. 2. Hence, the resistors inherently force corresponding voltages and currents to represent head losses and flow rates in accordance with the Hazen-Williams formula. The fundamental principle of operation of the nonlinear resistors depends upon the change in resistivity

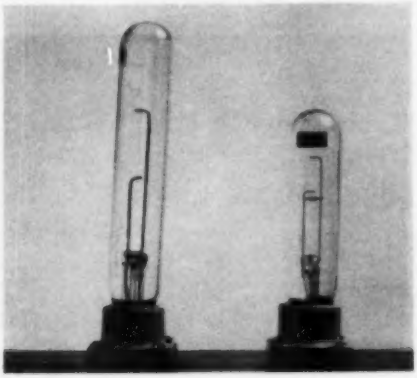

FIG. 5. Nonlinear Resistors

which accompanies the change in temperature of a tungsten filament and upon the temperature distribution along the filament, as affected by radiation of heat to the surroundings and by conduction of heat to the leads. As the current through a filament increases, the filament becomes hotter; its resistance rises; and the voltage drop—which is the product of current and resistance—increases as the desired exponential function of the current. The availability of tungsten in suitable diameters, its stability and long life and its peculiar resistance property make it a suitable material for the filaments. The nonlinear resistors resemble incandescent lamps of the showcase type, but the dimensions of the parts are specifically designed to meet the requirements of Eq. 2 rather than to make the units efficient as sources of light. Each resistor consists of a single, straight, uncoiled tungsten filament supported by nickel leads in an evacu-

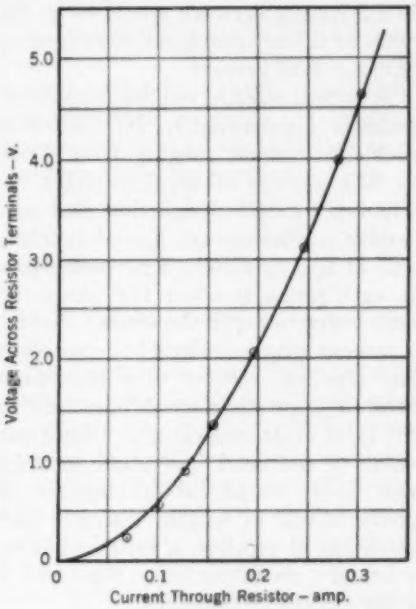

FIG. 6. Comparison of Test Results With Desired Characteristic

ated glass bulb. The bulb is sealed to a standard Edison screw base, which may be inserted in any of the sockets provided for that purpose in the pipeline network analyzer. Figure 5 is a photograph of two resistors having coefficients of 1.44 and 106.

The relation between test results and the desired exponential volt-ampere characteristic for a typical nonlinear

resistor having a coefficient of 42 is shown in Fig. 6. The solid curve portrays the desired characteristic according to Eq. 2, and the individual points are plotted from results of an actual test. The match is excellent except for voltages lower than one. In this low voltage range, a small deficiency in head loss indication occurs. Statistical studies show that the cumulative effect of these small errors on total head losses in a complete network would be of the order of 0.5 per cent if no other sources of error were present.

A normal stock of nonlinear resistors includes approximately 200 different coefficient values, ranging from 0.058 to 500, a ratio of roughly 10,000:1. The resistors are designed so that successive coefficients are spaced at intervals of approximately 5 per cent; that is, each rating is about 1.05 times the next lower rating in the series. Hence, a resistor may be selected to represent any pipeline, subject to a maximum error of approximately 2.5 per cent in the value of its coefficient, k. Since one value of the head loss coefficient, k_p, may apply to an infinite number of combinations of length, diameter and condition of pipeline, a resistor having a certain coefficient may represent a great variety of pipelines.

The range of voltage through which all resistors obey the requirements of Eq. 2 should be sufficiently large to permit convenient reading of the head losses within the range normally found in the pipelines of a network, but the voltages should not be so high that the total voltage drop across a complete network is hazardous to the operator of the analyzer. Suppose, for example, that ordinary 115-v. lamps happened to have the desired exponential characteristic and were used in a network containing 40 pipelines in series. The average voltage during an analysis would be about 60 per lamp, giving a total drop of 2,400 v. across the network. Obviously, it would be undesirable to operate an analyzer at this voltage level. The resistors are designed to operate normally in the range of 0–5 v. Their characteristic closely follows the exponential law up to the melting point of tungsten at about 12 v., but the resistors should not be operated at more than 4.6 v. for extended periods, in the interest of long life. In normal operation, the average voltage drop per resistor in a network is about 2.5 v.

FIG. 7. Resistors in Operation

Therefore, an electric network representing 40 pipelines in series, such as a 20 by 20 grid, would operate with approximately 100 v. between its most widely separated terminals. Voltages up to 300, representing 120 pipelines in series, are satisfactory for use in the analyzer without resort to alternating current and isolating transformers.

The temperature at the midpoint of any resistor filament is approximately the same for any given filament voltage, regardless of the value of the resistor coefficient. This relation is very useful, for it means that the value of head loss in a pipeline of any length or diameter

is closely indicated by the brightness of the incandescent filament of the corresponding resistor. Hence, the operator of the analyzer knows what portions of a network have the largest head losses simply by observing the filaments. He may then measure the values of the head losses which are significant without troubling to record all the head losses in a network unless he wishes to make a complete analysis. Figure 7 is a photograph of a set of resistors in operation during an analysis. The two resistors with the brightest filaments correspond to the pipelines with the largest head losses.

The properties of each nonlinear resistor may be summarized thus:

1. Its volt-ampere characteristic is analogous to the head loss–flow characteristic of a pipeline as expressed by the Hazen-Williams formula. The resistor may also be used to represent Darcy's law, as explained later.

2. Its coefficient may be selected from a series of approximately 200 numbers, so that it represents the head loss coefficient of a pipeline subject to a maximum error of approximately 2.5 per cent.

3. Its filament operates with a brightness which is closely related to the voltage across the resistor. The brightness therefore indicates the approximate magnitude of the head loss along the corresponding pipeline.

Conduct of Analysis

Preparation of Network Map

The first step in preparing for an analysis is to make a schematic diagram of the pipeline network, showing the operating conditions assumed to exist at all loads and sources. Opposite each pipeline is given the value of its head-loss coefficient, k_p, found from Eq. 3:

$$k_p = Ml \quad \ldots\ldots\ldots (3)$$

in which l is the pipeline length in 1,000-ft. units; and M is a constant determined from the following expression, in turn derived from the Hazen-Williams formula as shown in Eq. A6 of Appendix A:

$$M = \frac{5{,}830}{d^{4.87}C^{1.85}} \quad \ldots\ldots\ldots (4)$$

In Eq. 4, d is the internal diameter of the pipe, in feet, and C is the Hazen-Williams smoothness coefficient. Values of M may be read directly from a table.

An example of a schematic network diagram suitable for analytical work is given in Fig. 8, which is taken from a study of a portion of the municipal water distribution system of Winnipeg, Man. The values of all hydraulic quantities in this diagram (the underscored numbers are flow rates, in mgd.; the other decimals are head loss coefficients, k_p) must be converted to the corresponding values in the analogous electric circuit, Fig. 9 (where the underscored numbers indicate the amperage and the encircled numbers are resistor coefficients, k), before the pipeline network analyzer can be arranged for operation. The next step in preparing for the analysis is to select appropriate scales for this conversion.

Conversion Scales

The two basic scales are those relating voltage to head loss and current

to flow rate. Let these scales be called, respectively, B and G. Then:

$$B = \frac{V}{H}, \text{ volts per unit head} \quad \ldots (5)$$

$$G = \frac{I}{Q}, \text{ amperes per unit flow} \quad \ldots (6)$$

Values of these factors are selected from a list of preferred numbers which permit easy reading of the scales on the master voltmeter and ammeter. The value of B is chosen so that the average voltage per resistor in series will be roughly 2.5, and a value of G is selected which gives load currents suitable for the ratings of the available load devices. The values chosen for B and G fix the value of the factor, θ, which relates the nonlinear coefficients, k, to the head loss coefficients, k_p, of the corresponding pipelines.

The value of θ is:

$$\theta = \frac{k}{k_p} \quad \ldots (7)$$

If H is expressed in feet of water:

$$\theta = \frac{1.807B}{G^{1.85}} \quad \ldots (8)$$

with the unit flow expressed in mgd., or:

$$\theta = \frac{0.0501B}{G^{1.85}} \quad \ldots (9)$$

with the flow rate in 100-gpm. units. The derivations of Eq. 8 and 9 are given in Appendix B.

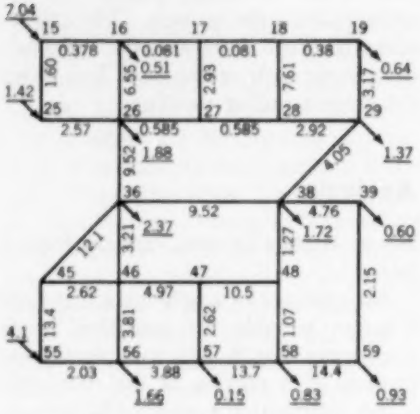

FIG. 8. Pipeline Network Diagram

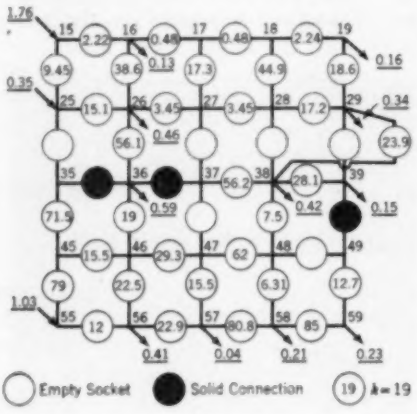

FIG. 9. Analogous Electric Circuit

In the present example, let the values of B and G be 0.25 v. per foot of head and 0.25 amp. per mgd., respectively. Then, from Eq. 8:

$$\theta = \frac{1.807(0.25)}{(0.25)^{1.85}} = 5.90 \quad \ldots (10)$$

Each value of k_p in Fig. 8 is multiplied by 5.90 to determine the value of the coefficient, k, of the corresponding nonlinear resistor in Fig. 9. The value of each load and source flow rate in Fig. 8 is multiplied by G, or 0.25, to obtain the corresponding current shown in

Fig. 9. These changes of scale for all known values in the pipeline network are the only computations required in the direct electrical-analogy method after the pipeline head loss coefficients have been determined.

Operation of Analyzer

After the scales for use in the analysis have been chosen, and the final circuit diagram similar to Fig. 9 has been prepared, the analyzer is placed in operation. There are three steps in conducting an analysis: [1] connecting the resistors to represent the pipeline network, [2] adjusting loads and sources to represent required conditions and [3] recording flow rates and head losses.

1. *Connecting the analyzer.* The first step in connecting the analyzer for operation is to insert in the proper sockets the resistors whose coefficients have values as close as possible to the values of k given in the circuit diagram, Fig. 9. If several locations in the circuit require resistors of the same rating, a single resistor having a coefficient suitable for representing a certain pipeline may not be available. Two alternatives are then possible: either to use two resistors in series, with the sum of their coefficients having the desired value, or to use resistors in parallel. If n identical parallel resistors are used, the value of each individual coefficient, k', should be:

$$k' = kn^{1.85} \quad \ldots\ldots\ldots (11)$$

which, for two resistors in parallel, requires that each should have a coefficient 3.6 times as large as the desired combined coefficient, k. An infinite variety of parallel combinations of unlike resistors may be chosen with the aid of a logarithmic graph based on principles similar to those used in determining equivalent pipes.

After the resistors are inserted in the sockets, flexible jumpers are connected between sources and the network and between the network and load device locations. These jumpers are indicated by arrows in Fig. 9. The final step in connecting the network is to mount a load device of appropriate current rating at each load location on the control panel, shown at the lower right in Fig. 2.

2. *Adjusting loads and sources.* After all connections have been completed, the analyzer is energized by a low voltage from the d-c. source. This voltage is gradually raised, while the operator watches the resistor filaments. The resistors which begin to glow brightly during this operation are likely to burn out when full voltage is supplied. To prevent damage to these resistors, the network is deenergized and the critical resistors are replaced by equivalent series combinations. The source voltage is again increased, while the operator observes the filaments of the load devices to ascertain that they do not glow brighter than a normal cherry red. Occasional adjustments of the series rheostats mounted on the load devices keep the load currents within the desired operating ranges. Since each load device maintains approximately constant current, the adjustment of other load devices to hold their proper currents has a negligible effect on it, and the desired values of currents in all load devices are quickly obtained, regardless of the voltages across them. The required source currents or voltage differences between pairs of sources are reached by adjusting the source control rheostats.

3. Recording flow rates and head losses. When all load and source conditions are properly met, the values of the hydraulic quantities may be measured. If the operator desires to determine the effect of a certain proposed plan quickly, he need not record the flow rates and head losses for all the pipelines. For example, in a study of the water distribution system on the Cornell campus, where the principal grid contains 61 pipeline elements, the value of the total friction head loss between the present reservoir and the site of an assumed fire-fighting demand was determined for each of seven different fire locations, without recording any other values. For each fire location, the time consumed in replacing certain resistors with equivalent series combinations, followed by adjustment of loads, was about 25 minutes. As soon as each readjustment was complete, the desired reading of total head

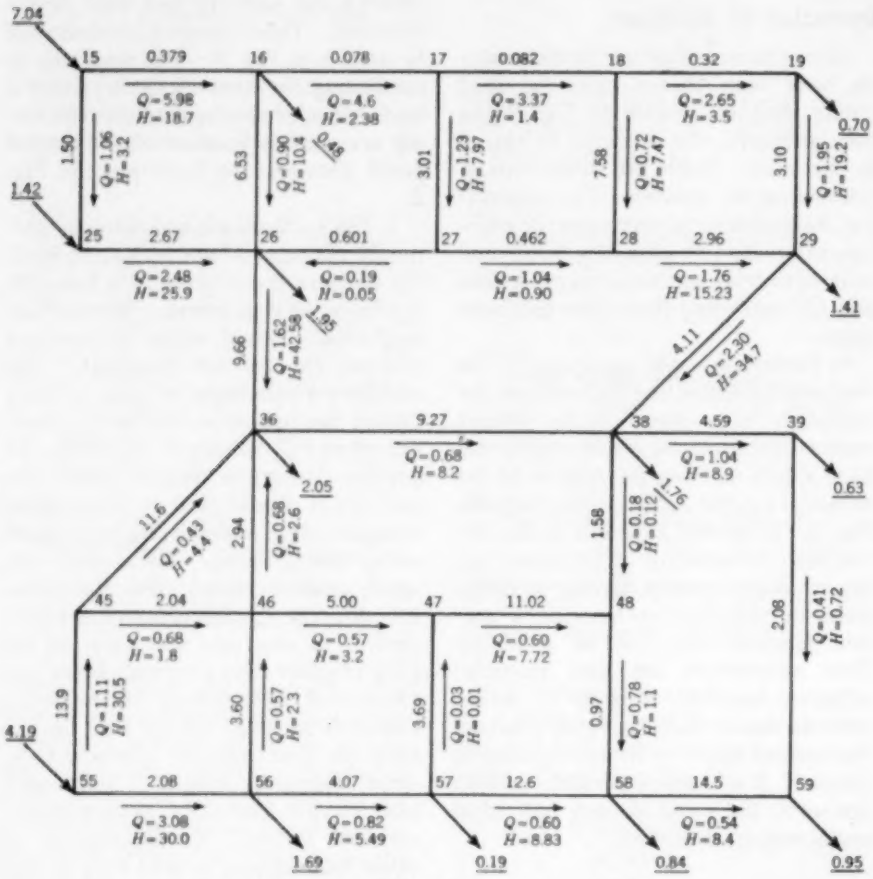

FIG. 10. Flows and Head Losses in Final Balance

loss was taken. The seven measurements were then repeated to determine the effect of a proposed new main supplying the campus grid directly from a pumping station, augmenting the supply from the present reservoir. A decision was quickly reached on the point where this new main could be effectively connected to the campus grid at least cost. The rapidity with which information can be obtained from the analyzer, results from the completeness of the analog made possible by the nonlinear resistors. The analyzer is, in effect, a small-scale water distribution system.

If detailed study of the performance of individual pipelines is needed, the operator records flow rates and head losses on the schematic pipeline network, as in Fig. 8. The flow rate for each pipeline is found from the special scale mounted on the master ammeter, with the current-diverting plug inserted in the proper jack. The head loss is found from the special scale on the master voltmeter, with the voltmeter leads connected to the jacks which represent pipeline junctions. The validity of the two readings taken for a pipeline may be checked by means of a nomograph which gives the value of the head loss coefficient that, according to the Hazen-Williams formula, corresponds to the measured values of flow and head loss. This check discloses any errors made in selecting resistors or in connecting the circuit and assures useful results. Two other checks may be made during the recording process. The first ascertains that the sum of flows approaching each junction equals the sum of flows leaving it. The second compares the sum of clockwise head losses around each loop with the sum of counterclockwise losses. These checks prevent the possibility of error in reading an instrument scale. The checks made during an analysis should show that loop head losses and junction flows are not out of balance more than approximately 2 per cent. A final evaluation of accuracy can be made, if desired, as described below.

Evaluation of Accuracy

The accuracy of an analysis may be judged by determining all the errors in head loss which accompany a balanced set of results. It is first necessary to adjust the slight discrepancies which may be present in the recorded values of head losses and flows, in order to make all balances perfect. The next step is to compute or find from a nomograph a value of head loss coefficient, k_p', which corresponds to the adjusted values of flow and head loss for each pipeline. The expressions used for this purpose are:

$$k_p' = \frac{0.554H}{Q^{1.85}} \quad \ldots\ldots (12)$$

with H expressed in feet and Q in mgd., or:

$$k_p' = \frac{19.95H}{Q^{1.85}} \quad \ldots\ldots (13)$$

with H in feet and Q in 100-gpm. units. The ratio of this derived coefficient to the desired coefficient, k_p, minus one, gives an error ratio. This ratio, multiplied by the measured head loss, determines the value of the error in feet of head loss for each pipeline.

An example of an error study, based upon an actual analysis of the network of Fig. 8, follows. Balanced values of head losses and flows are shown in Fig. 10, together with the values of

TABLE 2

Head Loss Errors in Fig. 10

Pipeline	1	2	3	4	5	6	7
	k_p'	k_p	$\frac{k_p'}{k_p}$	Error Ratio	Head	Positive Error	Negative Error
					ft.		
15–16	0.379	0.378	1.002	0.002	18.7	0.037	
16–17	0.078	0.081	0.963	−0.037	2.38		0.088
17–18	0.082	0.081	1.011	0.011	1.40	0.015	
18–19	0.32	0.38	0.842	−0.158	3.50		0.554
15–25	1.50	1.60	0.938	−0.062	3.2		0.198
16–26	6.53	6.55	0.997	−0.003	10.4		0.031
17–27	3.01	2.93	1.012	0.012	7.97	0.095	
18–28	7.58	7.61	0.995	−0.005	7.47		0.037
19–29	3.10	3.17	0.978	−0.022	19.2		0.422
25–26	2.67	2.57	1.04	0.04	25.9	1.038	
26–27	0.601	0.585	1.028	0.028	0.05	0.001	
27–28	0.462	0.585	0.79	−0.21	0.90		0.189
28–29	2.96	2.92	1.012	0.012	15.23	0.183	
26–36	9.66	9.52	1.014	0.014	42.58	0.596	
29–38	4.11	4.05	1.017	0.017	34.7	0.590	
36–38	9.27	9.52	0.972	−0.028	8.2		0.230
38–39	4.59	4.76	0.963	−0.037	8.9		0.329
36–45	11.6	12.1	0.96	−0.04	4.4		0.176
36–46	2.94	3.21	0.915	−0.085	2.6		0.221
38–48	1.58	1.27	1.243	0.243	0.12	0.029	
39–59	2.08	2.15	0.968	−0.032	0.72		0.023
45–46	2.04	2.62	0.78	−0.22	1.8		0.396
46–47	5.00	4.97	1.006	0.006	3.2	0.019	
47–48	11.02	10.5	0.952	−0.048	7.72		0.371
45–55	13.9	13.4	1.038	0.038	30.5	1.160	
46–56	3.6	3.81	1.372	0.372	2.3	0.858	
47–57	3.69	2.62	1.41	0.41	0.01	0.004	
48–58	0.97	1.07	0.905	−0.095	1.1		0.105
55–56	2.08	2.03	1.025	0.025	30.0	0.750	
56–57	4.07	3.88	1.05	0.05	5.49	0.274	
57–58	12.6	13.7	0.92	−0.08	8.83		0.706
58–59	14.5	14.4	1.007	0.007	8.4	0.059	
				Total	317.87	5.708	4.076

coefficients, k_p', derived from them. A summary of results and errors is presented in Table 2. Corresponding values of k_p' and k_p are listed in Columns 1 and 2, respectively, and their ratios are listed in Column 3. The final error in head loss is given in Column 6, if positive, or in Column 7, if negative. The total positive error in head loss is 5.7 ft., and the total negative error is 4.1 ft., compared with a total value of 318 ft. for all head losses. Similar general results of all analyses conducted on the Cornell analyzer up to the time this paper was written are presented in Table 3. The maximum net error—

that is, the difference between positive and negative errors—in these analyses is 2.5 per cent of the total head loss.

The overall error in an analysis has always been found conservative; that is, it tends to produce a total head loss slightly larger than that obtained from the Hazen-Williams formula. The error associated with the electrical-analogy method is believed to be small compared with the probable error in assigning values of smoothness coefficients to the pipelines in a network. The error caused by inserting the ammeter in the circuit to indicate flow is negligible whenever the resistor voltage is significant, but, as the voltage approaches zero, corresponding to a very low head loss, the resistance of the ammeter circuit may occasionally be comparable to that of the resistor in series with it. In these instances, the head loss in the pipeline represented by the resistor is so small that accurate evaluation of flow rate or head loss is usually unnecessary. If maximum accuracy is desired for these lightly loaded pipelines, the best procedure is to measure the head losses without inserting the ammeter in the circuit to measure flows. The flow rate corresponding to the measured head loss may then be found from a nomograph.

Another way to judge the accuracy of an analysis is to determine the percentage error in head loss for each pipeline, referred to the maximum head loss between any pair of points in a network. For example, in Fig. 10, the largest head loss, 89.5 ft., which occurs between points 15 and 59, is the base for evaluating error percentages. The frequency distribution of errors computed in this manner for all the analyses listed in Table 3 is presented as a histogram in Fig. 11. The mean value of error in head loss for individual pipelines is positive, and equals 0.13 per cent of the maximum head loss. Eighty-seven per cent of all errors are within the range of ± 1 per cent of the maximum head loss. All errors larger than 2.2 per cent are positive, and the largest single error is 4.4 per cent of the maximum network head loss.

TABLE 3

Summary of Total Errors

Analysis	No. of Pipelines	No. of Loops	Head Loss—*ft.*			Net Error *ft.*	Net Error *per cent*
			Total	Positive Error	Negative Error		
Winnipeg 1A	32	11	318	5.7	4.1	1.6	0.5
Winnipeg 1B	64	26	209	9.6	6.6	3.0	1.4
Winnipeg 2A	34	13	382	14.6	5.1	9.5	2.5
Winnipeg 2B	35	14	318	12.7	6.7	6.0	1.9
Winnipeg 3A	34	13	235	7.3	3.8	3.5	1.5
Winnipeg 3B	34	13	223	7.2	4.0	3.2	1.5
Cornell 21	61	20	286	14.0	7.7	6.3	2.2
Cornell 25	39	14	193	5.4	4.9	0.5	0.3

The error studies show that the direct electrical-analogy process of pipeline network analysis gives results the accuracy of which is better than that of the values usually assumed for the

smoothness coefficients and load flow rates of a water distribution system. After a period of familiarization with the process, the engineer responsible for an analysis should ordinarily not need to make an error study, if the suggested checks have been performed during the recording of head losses and flows.

Use of Darcy's Law

If the condition of the internal surface of a pipeline is known exactly, the relation between head loss and flow rate

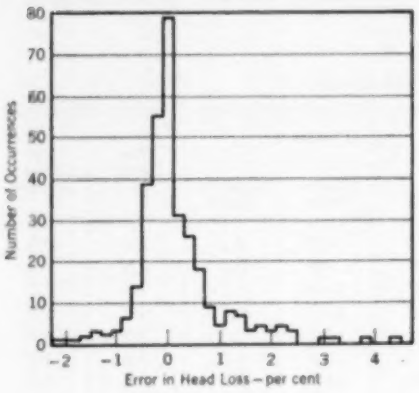

FIG. 11. Distribution of Error

can be expressed more accurately by Darcy's law than by the Hazen-Williams formula. In Darcy's law, the surface condition is given in terms of the friction factor, f, which varies with the flow rate, whereas, in the Hazen-Williams formula, the condition is represented by the smoothness coefficient, C, which is considered constant.

A typical comparison between the Hazen-Williams formula and Darcy's law is presented in Fig. 12, which applies to a line of 10-in. pipe 1,000 ft. long. The solid curve (A) portrays the relation between head loss and flow rate according to Darcy's law, for a pipe having a relative roughness of 0.0016, as defined by Moody (7); and the broken curve (B) shows the relation according to the Hazen-Williams formula, for $C = 120$. The curves intersect at a flow rate of 1,225 gpm., or a velocity of 5 fps., and are very close to one another over the range of velocity 0–7 fps. Hence, the Hazen-Williams formula with $C = 120$ should be satisfactory for this range of velocity. Suppose, however, that the flow rate

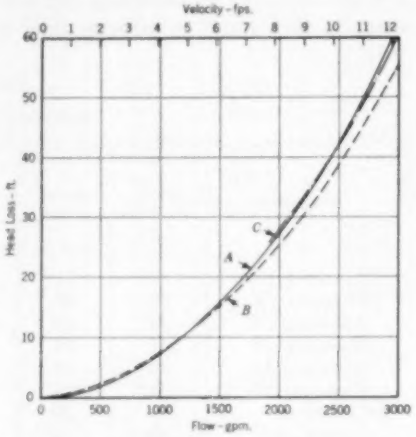

FIG. 12. Comparison of Darcy's Law and Hazen-Williams Formula

found from a test in the pipeline network analyzer is 2,450 gpm., corresponding to a velocity of 10 fps. The discrepancy between Darcy's law and the Hazen-Williams formula is then significant; but if the value of the head loss coefficient, k_p, of the pipeline is appropriately increased, the Hazen-Williams formula gives an excellent representation of the pipeline performance. The dash-dot curve (C) in Fig. 12 is based upon the Hazen-Williams formula with the value of k_p 10 per cent larger than that used for curve B.

Figure 13 gives the values of a correction factor by which any pipeline coefficient, k_p, or corresponding resistor coefficient, k, should be multiplied in order to provide close agreement with Darcy's law. The curves are drawn for $C = 100$ for pipelines from 4 to 16 in. in diameter, and for $C = 120$ for pipelines from 10 to 30 in. in diameter. Correction factors greater than 1 have the same values for either value of C. Similar curves could be prepared for other values of C. The coefficient of line characteristics correctly at a velocity of 5 fps. Within a velocity range of 0–7 fps., the small errors in head loss in a network tend to compensate, since they are either positive or negative as the velocities in the various pipelines are less or more than 5 fps. Resistors whose coefficients correspond to the selected values of C are placed in the analyzer, which is then operated according to required conditions of input and discharge. The flow rate is measured for the resistors whose filaments

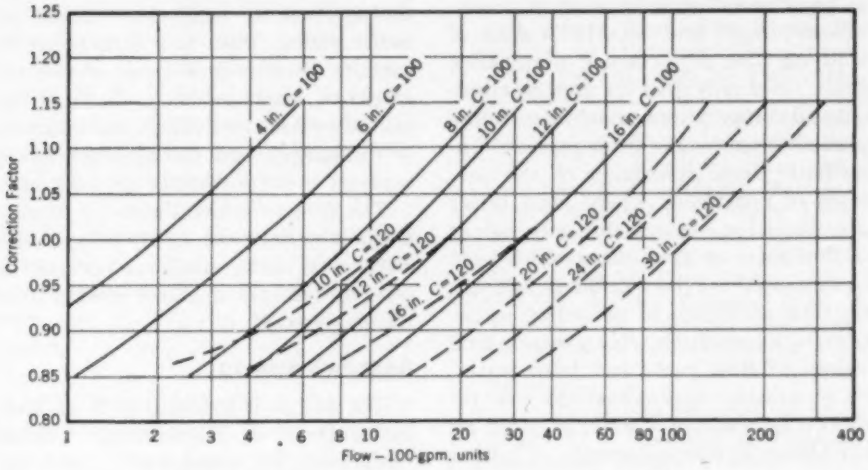

FIG. 13. Relation of Correction Factor to Flow Rate

any pipeline is chosen to be correct for the given value of C if the velocity is 5 fps. At the flow rate for any other velocity, the correction factor may be found from the appropriate curve. For example, the head loss coefficient of a 10-in. pipeline in which the flow rate is 2,450 gpm. should be multiplied by 1.10, as previously suggested.

At the beginning of an analysis, the velocities in the various pipelines of a network are unknown. Let values of C be chosen which represent the pipe- are glowing brightly, and values of correction factors to apply to the resistor coefficients are found from Fig. 13. The resistors are then replaced with others having suitably altered coefficients, and the final complete analysis may be conducted. The results of this analysis will be in close agreement with Darcy's law. The substitution of resistors causes a slight redistribution of currents in the network elements, but the changes are so small that the resistors operate well within the range

of satisfactory representation of the pipeline characteristic.

This procedure for conducting a refined analysis is believed to be necessary only seldom but is described to show the possibility of using the electrical-analogy method for occasional problems involving a range of velocities for which the Hazen-Williams formula may be considered unsuitable.

Conclusion

The direct electrical-analogy method of pipeline network analysis is a convenient, rapid and accurate means of studying the performance of pipeline grids. Not only does the method eliminate all computations which involve the plan of the network, but it provides immediate visual indication of the sections of a network where head losses are excessive. Since the only values of flow rates or head losses which need be measured are those of direct interest, no time is wasted in recording unimportant information. No guesses, trial values of flow rates and head losses, or successive approximations are required in reaching a solution based on the Hazen-Williams formula. Changes to represent alternate plans of construction or different operating conditions at the sources or loads can easily be made, and their effects can be measured rapidly. Hence, the method is a useful aid in designing networks for maximum economy, as well as in analyzing their performance in detail.

If doubt exists concerning the physical conditions of pipelines in an existing network which is to be analyzed, a field check of pressures at a few important locations under normal load conditions may be made. The analyzer may be matched to field conditions by changing the values of resistor coefficients or by shifting load distributions. When this match is satisfactorily accomplished, the network may be analyzed, and the effects of new conditions or changes in the network plan may be determined with the assurance that the unchanged portions of the network are correctly represented.

In addition to studies of specific problems, the electric pipeline network analyzer can be used to examine the effects of variations in the factors controlling the conditions of analyses in general. Examples of these effects are the increase in head loss caused by skeletonizing, head loss errors due to random distributions of smoothness coefficients, improper flow distributions caused by incorrect values and locations of discharges, and the accuracy of an analysis as a function of network size.

The direct electrical-analogy process is easily understood. Any person with a technical background can operate the pipeline network analyzer after a brief training period.

Acknowledgment

The author is indebted to S. C. Hollister, Dean, of Engineering, Cornell University, for allocating the principal funds for the construction of the pipeline network analyzer. The Standard Electric Time Co., Springfield, Mass., made a further contribution to the project, which assured its completion, and gave valuable aid in designing and constructing the analyzer and the current-diverting jacks. The basic principle for these jacks was suggested by Prof. L. A. Burckmyer. Engineers of Sylvania Electric Products, Inc., Salem, Mass., designed the enclosures for and methods of mounting the filaments of the nonlinear resistors, which were constructed by their firm according to specifications furnished by the author.

The basic research underlying the development was conducted as the subject matter of a doctor's thesis (8) at Massachusetts Institute of Technology, under the supervision of Harold L. Hazen, Head, Dept. of Electrical Engineering, for whose inspiring counsel the author is especially grateful. The original idea for an electric pipeline network analyzer was conceived about 1930 by Thomas R. Camp, then associate professor of sanitary engineering at M.I.T., who later assisted the author by sharing his knowledge of hydraulic aspects of the problem and encouraging him in every way. Professors A. T. Gifford, G. P. Wadsworth, H. C. Hottel and A. T. Ippen also devoted much time to the discussion of various aspects of the problem of pipeline network analysis.

N. S. Bubbis, then Acting Gen. Mgr., Greater Winnipeg Water Dist., Winnipeg, Man., kindly transmitted several practical problems to test the analyzer, and R. H. Ellis, engineer of the Standards Div., Associated Factory Mutual Fire Insurance Companies, Boston, Mass., formulated the study of the Cornell campus water distribution system and participated in operating the analyzer during the study. Many practicing engineers contributed maps of typical pipeline networks and other information to orient the author in the operation of water distribution systems. He expresses his sincere thanks for their help, and his regret that the need for brevity prevents mentioning each by name.

D. F. Gunder, Head, Dept. of Engineering Mechanics, Cornell University, kindly reviewed the manuscript and gave helpful suggestions concerning it. W. L. Reese and R. C. Rustay operated the analyzer for the tests mentioned in the paper.

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APPENDIX A—Derivation of Equation for Head Loss Coefficient

The original form of the Hazen-Williams formula relating friction head loss to the rate of water flow in a pipe is:

$$v = 1.318Cr^{0.63}s^{0.54} \quad \text{(A1)}$$

in which C is the smoothness coefficient; r is the hydraulic radius, equal to $\frac{d}{4}$, with d the inside diameter, in feet; s is the friction head loss, expressed in feet of water per foot of pipe length; and v is the average velocity of water, in feet per second. Since the rate of flow, Q, in gpm., is $353d^2v$:

$$v = \frac{Q}{353d^2} \quad \text{(A2)}$$

The friction head loss per 1,000 ft. of pipe is found by taking the 1.85 power of both sides of Eq. A1 and multiplying by 1,000:

$$1{,}000s = \frac{1{,}000}{1.667\left(\frac{d}{4}\right)^{1.167}} \cdot \frac{v^{1.85}}{C^{1.85}} \quad \text{(A3)}$$

Let the value of v from Eq. A2 be substituted in Eq. A3:

$$1{,}000s = \frac{600}{\left(\frac{d}{4}\right)^{1.167}C^{1.85}}\left(\frac{Q}{353d^2}\right)^{1.85} \quad \text{(A4)}$$

$$1{,}000s = \frac{0.0583}{d^{4.87}C^{1.85}}Q^{1.85} \quad \text{(A5)}$$

the result being in terms of feet of water per 1,000 ft. of pipe.

Since it is usually more convenient to use larger numbers than the values of $1{,}000s$ obtained from Eq. A5, multiplying the coefficient of $Q^{1.85}$ by 10^6 has been suggested, which gives as the value of the constant, M, for a pipe *1,000 ft.* long:

$$M = \frac{5{,}830}{d^{4.87}C^{1.85}} \quad \text{(A6)}$$

The constant, M, in Eq. A6 is expressed in units of 10^{-6} ft. of water friction head loss per 1,000 ft. of pipeline. The head loss coefficient for insertion on the pipeline network map for a pipeline l thousand feet long is then:

$$k_p = Ml \quad \text{(A7)}$$

as in Eq. 3.

APPENDIX B—Relations Among Scales

If the flow rate, Q, is expressed in mgd.:

$$H = 10^{-6}k_p(694.4Q)^{1.85}$$
$$H = 1.807k_pQ^{1.85} \text{ ft.}$$

H being the friction head loss, in feet; k_p, the pipeline coefficient; and k, the resistor coefficient. The relationships among the scales are:

$$G = \frac{I}{Q} \text{ amp./mgd.}$$

$$B = \frac{V}{H} \text{ v./ft. head loss}$$

$$k = \theta k_p$$

$$k = \frac{V}{I^{1.85}}$$

$$k_p = \frac{H}{1.807Q^{1.85}}$$

$$\theta = \frac{k}{k_p} = \frac{V}{I^{1.85}} \cdot \frac{1.807Q^{1.85}}{H}$$

$$= \frac{1.807B}{G^{1.85}}$$

If the flow rate, Q, is expressed in 100-gpm. units:

$$H = 10^{-6}k_p(100Q)^{1.85}$$
$$H = 0.0501k_pQ^{1.85} \text{ ft.}$$

H being the friction head loss, in feet; k_p, the pipeline coefficient; and k, the resistor coefficient. The relationships among the scales are:

$$G = \frac{I}{Q} \text{ amp./100 gpm.}$$

$$B = \frac{V}{H} \text{ v./ft. head loss}$$

$$k = \theta k_p$$

$$k = \frac{V}{I^{1.85}}$$

$$k_p = \frac{H}{0.0501Q^{1.85}} = \frac{19.95H}{Q^{1.85}}$$

$$\theta = \frac{k}{k_p} = \frac{V}{I^{1.85}} \cdot \frac{Q^{1.85}}{19.95H}$$

$$= \frac{0.0501B}{G^{1.85}}$$

Benefited Water District Plan for Main Extensions

By Dale L. Maffitt

A paper presented on Oct. 6, 1949, at the Iowa Section Meeting, Burlington, Iowa, by Dale L. Maffitt, Gen. Mgr., Water Works, Des Moines, Iowa.

THE fact that most American cities are continually expanding around the periphery provides a familiar problem for the engineers in charge of water distribution systems. There are, of course, varied opinions on the practicability of municipalities' furnishing water to consumers beyond their corporate limits.

It is more or less common practice for municipally owned water works to provide service outside the city, but the entire expense of the construction and maintenance of mains is often borne by the property owners benefited, and, if fire protection is provided, it has to be at a rate fixed by the municipality supplying the service. Also, in order not to discriminate against water users within the corporate limits, who are called upon to finance the utility's main plant and properties, it is the usual custom to charge more for water, on a gallonage basis, outside the city.

Although small areas may be handled by making direct contacts with individuals, it often becomes practical, when large sections outside the corporate limits are to be served, to establish "benefited water districts." Since 1924 Iowa has had a law providing for the establishment of such districts, but not until the statute was amended and rewritten in 1939 was it very much used. Eight benefited water districts have been approved by the supervisors in Polk County, Iowa, all to be supplied from the system of the Des Moines Water Works. Five of these districts were formed in 1949, while the other three date from before the war, which virtually stopped new main construction everywhere.

Chapter 357 of the 1946 Code of Iowa provides that:

> The board of supervisors of any county shall, on the petition of 25 per cent of the resident property owners in any proposed benefited water district, grant a hearing relative to the establishment of such proposed water district; such petition shall set out the following and any other pertinent facts: [1] the need of a public water supply; [2] the approximate district to be served; [3] the approximate number of families in the district; [4] the proposed source of supply; [5] the type of service desired, whether domestic only or for fire protection and other uses.
>
> The board of supervisors may, at its option, require a bond of the petitioners.

The source of supply for a benefited water district is usually, but not necessarily, the local water supply of the city to which the district is contiguous. If so, the law requires that the corporation or municipality which controls the proposed source of supply furnish a proposal in writing outlining the terms upon which water will be supplied to the district, or to the individuals within it.

If it is decided, at a proper public hearing by the board of supervisors, to

APPLICATION FOR SERVICE

(Water District No. 3)

APPLICATION NO._____ PERMIT NO._____

TO THE BOARD OF WATER WORKS TRUSTEES OF THE CITY OF DES MOINES, IOWA:

The undersigned applicant desires a supply of water from the Des Moines Water Works for domestic use for premises known as

_____

_____

_____

and located in Water District No. 3 in Webster Township, Polk County, Iowa, to be delivered through water mains owned by the Board of Water Works Trustees of the City of Des Moines, Iowa, installed and maintained pursuant to agreement between said Board and owners of real estate in said District dated May 27, 1940. Water shall be metered, size of meter to be determined by the manager of the Des Moines Water Works.

Applicant agrees to comply with the rules and regulations now in force or hereafter established and applicable thereto.

Such connection shall be made and service pipe and fixtures, including shut-off valve, stop box, meter box and other necessary fixtures shall be installed by a licensed plumber, licensed by the City of Des Moines, approved by said Board, and in accordance with its rules, regulations and requirements, and at the sole expense of the applicant, who shall thereafter own and maintain the same in good, serviceable and safe condition.

The applicant agrees to hold the said Board of Water Works Trustees and the City of Des Moines, Iowa, free and harmless from and on account of any claims for damages to persons or property growing out of or in any manner resulting from the use, condition, location, character, maintenance or presence of said connection pipe, and fixtures. The applicant agrees to pay for all water furnished at the times and at the rates now or hereafter prescribed by said Board, and will comply with all applicable rules and regulations of said Board. The said Board will not furnish any of the material or perform any part of the work necessary for installing the foregoing connection pipes and fixtures, unless special agreement is made therefor.

The undersigned further agrees to make such repairs to or changes in said pipe and fixtures as the manager of said Water Works may direct within five (5) days after receipt of notice in writing so to do. In the event of failure to comply with requirements, the undersigned agrees that the said Board may, without notice, turn the water off from said premises and cease supplying water thereto.

The agreements herein on the part of the applicant shall run with the land and be binding upon the heirs, administrators, successors and assigns of the applicant and of the owner of said premises.

This application is made subject to all of the conditions and provisions of the agreement aforesaid and applicant agrees to and shall be bound by all of the conditions and provisions thereof.

Des Moines, Iowa, _____, 19_____ _____

Applicant

METER ACCOUNT NO._____ _____

P. O. Address of Applicant

Approved for the servicing of water this _____ day of _____ 19____

BOARD OF WATER WORKS TRUSTEES

FIG. 1. Service Application Form

establish the benefited water district, it is then the duty of the supervisors to appoint a competent civil engineer to prepare a plat and a dummy schedule of proposed assessment.

When this preliminary design and assessment is approved by the supervisors, an election is held in the district. The proposition is deemed to have carried if a majority of the legal voters residing in the district votes in favor of it. At the same election, a board of trustees is elected to operate the proposed water system.

If satisfactory arrangements can be made to sell bonds for financing the project, bids are taken by the board of supervisors for construction of the mains in accordance with the plans of the engineer.

Terms of Proposal

Probably of first importance to water works officials are the terms to be included in the proposal furnished by the municipality or corporation controlling the source of water supply for the district. Such a proposal should include:

1. Specifications on the size and kind of pipe used and the location and type of connection with the mains of the supplier.
2. An agreement on how the water shall be metered and by whom the meters are to be furnished.
3. The terms of payment for water used, and where and by whom the bills are to be paid.
4. Copies of applications for service, or other forms of agreement, to be entered into between the customer and the supplier.
5. An agreement on the manner in which all pipes and appurtenances shall be maintained and who shall pay for the work.
6. Terms with respect to fire protection, if it is to be furnished.
7. An agreement regarding any possible claims for damages resulting from interruptions of service, inadequate pressure, discontinuation of service for nonpayment and so on.

Des Moines has encountered some developments in connection with the establishment and operation of benefited water districts which may be of interest. Among the more important are the following:

1. There has been a tendency to install mains of inadequate size, so that, when extensions become desirable, sufficient capacity is not available.
2. It has sometimes been found that the cost of extending the mains exceeds 25 per cent of the actual value of the property, which, according to the law, is the maximum amount of assessment that can be made.
3. The need for fire hydrants and mains of adequate size for them introduces a problem, as does also the question of fire sprinkler services and what charges should be made therefor.
4. Close and agreeable cooperation between the trustees of the district and the management of the water works furnishing the supply is necessary. The forms used for service and meter applications are important. Samples of the forms employed in Des Moines are available to those interested. A sample service application form is shown in Fig. 1.

Although there are still some weaknesses in the benefited district plan, for the most part it serves its purpose well.

Los Angeles Experience With Water Hammer

By Alexander C. Rener

A paper presented on Oct. 27, 1949, at the California Section Meeting, Sacramento, Calif., by Alexander C. Rener, Office Engr., Water Distr. Div., Dept. of Water & Power, Los Angeles.

WATER hammer has been the subject of numerous excellent technical papers given before this Association and many engineering societies. The matter has usually been treated on a highly technical level, with many mathematical formulas and graphs based on extensive experimentation. These papers, with their background of study, have been of tremendous value in developing remedies for water hammer and surges in trunk lines and pumping plants. In grid systems with branch lines, services, air valves, blow-offs and the many appurtenant structures, however, the complexity of conditions is such that the small water works operator, who probably is not an engineer, seeks a practical rather than an analytical solution to his problem. With that idea in mind, the subject will be treated in this paper on the basis of practical experience in the control of water hammer and surges in Los Angeles.

The water distribution system of Los Angeles is a vast network of different pressure zones, the area served varying in elevation from zero to 1,719 ft. above sea level. If each zone were fed from a tank or reservoir, there would be little trouble from water hammer in the distribution system. This method is impossible for many reasons, however, and a system of pressure regulators is used. The number of service connections per zone ranges from 20 to 150,000, and the 104 pressure-regulating stations vary from one 2-in. regulator to six 20- and three 12-in. regulators. Two types of valves are used for regulating water pressures: the globe type and the plug type, operated by a hydraulic cylinder. Experience has shown that the development of water hammer is equally possible with both kinds of regulator. The pilot valve maintains the same control on either type and, if the surge or hammer is checked before it reaches the valves, there will be little danger of serious situations occurring.

Regulators and Relief Valves

Water hammer and surges in a distribution system supplied through pressure regulators may be due to many factors. A failure in the pressure regulator may cause it to stay open, allowing high-pressure water to enter a low-service zone. This type of surge is controlled by pressure relief valves which are located on the low side within a few feet of the regulators. In years past pressure relief valves were installed primarily in locations close to storm drain catch basins, drainage channels or other convenient places, often thousands of feet from the pressure regulator. It has since been found, however, that relief valves must be situated very near the regulator in order to be effective. If the regulator remained open, the resulting pressure wave had to travel a long distance before it reached the relief valve. Dur-

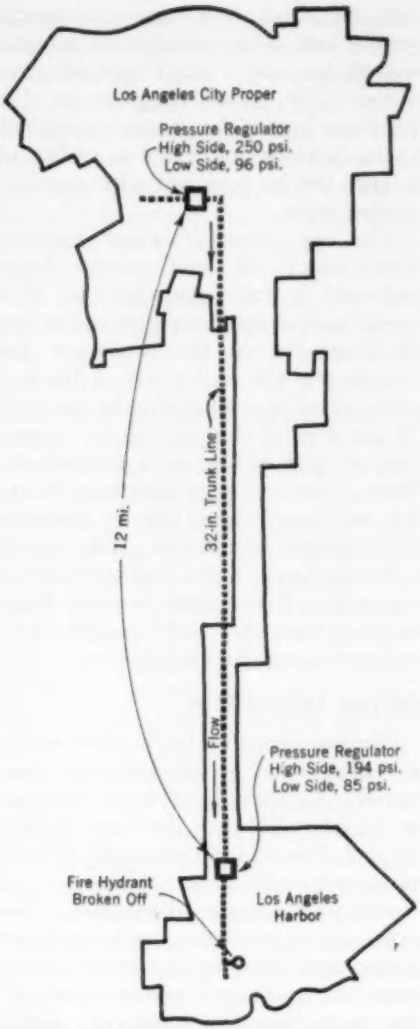

FIG. 1. Trunkline Supplying Water for Los Angeles Harbor

ing that interval the water main, consumers' service pipes and hot-water tanks were subject to damage.

The relief valve used by the Los Angeles Dept. of Water and Power is a standard pressure regulator with a reverse-acting pilot valve which causes it to open and discharge water in the event of an increase in pressure. This type of relief valve has been found most effective and operates perfectly if the rise in pressure is not too rapid. If the regulator should open too quickly, the time required to open the relief valve may allow a surge to enter the low-pressure zone. This problem is being solved by the development of more sensitive controls on the pilot valve which operates the relief valve. The valves are set to relieve after the pressure on the low side of the regulator rises 5–10 psi. above the normal operating figure. The waste water from the relief valve is diverted into storm drain catch basins, if possible, and, in the areas where there are no such facilities, water is spilled into the gutter. The wasting of water is generally reported by consumers as water running down the gutter or a probable broken pipe, and, with the aid of two-way radios, a regulator crew is immediately dispatched to remedy the situation.

The main problem in reducing water hammer to a minimum where regulators are used is to prevent the surge from reaching the pilot valve. This objective has recently been achieved successfully by the use of a new type of surge suppressor, in which the energy of the wave is absorbed in compressing air in a rubber and steel chamber. The suppressors have worked especially well when used in a station serving a closed system. This circuit routes the water from the low-pressure side through the surge suppressor; after the hammer has been suppressed, the pressure reaches the pilot valve, which operates the regulator more smoothly.

An interesting instance of the development of water hammer through pressure regulators as a result of sudden demand occurred recently. The Los Angeles Harbor water distribution system (Fig. 1) is separate from that

of the city proper except for a 32-in. trunk line 12 miles long. This line receives its water through pressure regulators, and the pressure is again reduced through pressure regulators as it enters the harbor area. A fire hydrant broke in the harbor area one night when the entire system was being supplied by the pressure regulators and a small pumping plant. The regulators opened to supply the demand, which, in turn, caused the regulators 12 miles away to open. These regulators are normally set at 96 psi. on the low side. The pressure immediately dropped to 80 psi., and the regulators overtraveled, causing the pressure to rise to 116 psi. and then to drop to 96. The flow rate changed from 7 to 40 fps. and back to 18 fps. Although the distribution system suffered no bad effects from this surge, it illustrates the danger and damage which could develop if a large water main burst.

A solution to this type of problem may be possible if a new mechanism, now being developed, is successful for use with the pilot valves at the regulators. This device will employ a circuit which will be more sensitive to changes in pressure. The pressure in the line on the low side will drop as before, but the pressure in the controls for the regulator will decrease only slightly and it will find a static position again before the pressure can rise. This attachment will require much experimentation and many tests before it is perfected but the endeavor is in the right direction.

Another solution could be the construction of a surge tank which would serve a dual purpose. In the event of a sudden demand, the small tank storage would be sufficient to allow the regulators to open more slowly and prevent water hammer. Also, at night, when the system is operating entirely from the regulators, the tank would absorb the shock if a large consumer's service line valve was shut off quickly enough to cause a water hammer condition. The natural sluggishness of a regulator is such that it cannot respond to the decrease in demand as swiftly as a large service equipped with a quick-closing valve.

The one phase of water hammer which affects all water systems, large and small, is that of gate closures. The crews used in operating gate valves are all instructed in the procedure for closure and are well aware of the importance of slow operation in the final 25 per cent of closure. In the operation of large valves, it is desirable to have a pressure gage upstream in order to observe any rise in pressure which might be harmful. The use of a pressure gage is the best method for controlling the closure because flows in trunk lines vary and it is difficult to estimate a definite closing time.

Service Connections

The problem of water hammer is also a consideration of the individual consumer. Complaints of water hammer and noise received by the Dept. of Water and Power are investigated by field inspectors who locate the source of trouble and recommend remedies. The rules and regulations governing water service authorize the department to inspect the consumer's premises and insist upon corrective measures. Complaints of water hammer are common from consumers who are getting water through 2-in. double cast-iron services. This type of line, installed during the 1920's and the early 1930's, consists of a 2-in. cast-iron bell-and-spigot pipe lateral from the street main to the curb, where two branch laterals, off a tee, are provided for adjoining properties. The trouble generally occurs because a neighbor has a faulty toilet valve or

faucet, or, more recently, an automatic washing machine or dishwasher with a quick-closing valve. The remedy for this type of water hammer is to install individual service pipes from the main in the street. By convincing the neighbor of the damage which may be done to his own plumbing by the chattering valves, he can be induced to correct the condition.

In the hill areas of Los Angeles, many consumers use individual pressure regulators equipped with relief valves because of the high pressure in the water mains. A reasonable pressure of approximately 40 psi. is maintained in the highest sections, which may cause a pressure of 200 psi. or more in the lowest areas. When the seats become worn, these individual-service regulator valves cause tremendous water hammer in the distribution system. Surges of 100 psi. have been recorded, and broken mains within the confined area of the regulated system could be attributed to this cause. The remedy, again, is to convince the consumer that repairs to his regulator are essential to protect the plumbing on his premises, because, if his regulator is set for 70 psi., a worn seat may allow pressures as high as 125 psi. should the relief valve fail.

Large consumers, such as factories, laundries, railroads and meat-packing concerns, with their quick-closing valves, are a great source of water hammer trouble. In one area, two main breaks occurred during a single day in a system operating at 65 psi. A short time later complaints were received about water hammer in the area, and 24-hour pressure recorders connected to fire hydrants in the vicinity showed a water hammer of 40 psi. between two and three each afternoon. An investigation of the premises of every business and manufacturing concern in the area revealed nothing. For nearly two years this problem continued, until, by a stroke of luck, an inspector found the trouble. Suspicion had finally centered around a large laundry, although the management assured the department of full cooperation. One afternoon the inspector connected a pressure recorder to the plumbing. As he walked to the rear of the building, he observed a workman spinning the wheel valve on a 2-in. gate attached to a backwash apparatus for cleaning the machines. The recorder showed the water hammer, and the problem was quickly solved by the management when it replaced the valve with one which could not be closed rapidly. The workman had been properly instructed but it was easier to spin the wheel when no one was looking. This incident proves once again that the human element is often the cause of water hammer difficulties.

Fire Hydrant Testing

The more than 25,000 fire hydrants in the Los Angeles water distribution system are tested every three months by members of the fire department, to find faulty valves and keep the hydrants in excellent operating condition. This check is not considered a fire flow test because of the small amount of water discharged.

The rule for testing fire hydrants has been established for many years, and, with experience, methods have been developed to eliminate the probability of water hammer. At first the fire hydrants were tested by opening the hydrant valve. If the valve or rubber was loose, however, the valve might slam shut, causing tremendous water hammer and resulting in broken mains, service connections, consumer's plumbing and water heaters. There

were also many dirty-water complaints, because the hydrants were opened and closed before the system could clean out the sediment stirred up by flow reversal.

The present method of testing fire hydrants, which is incorporated in the rules and regulations of the fire department, involves a relatively simple apparatus, consisting of a cap that fits over the fire hydrant nipple, a ½-in. pipe, wheel valve and rubber hose, and a pressure gage (Fig. 2). The test apparatus is attached to the hydrant nipple and the ½-in. wheel valve left open. The fireman then starts to open the hydrant valve slowly for one or two turns. If the water begins flowing after the first turn of the spanner wrench, the hydrant valve is fully opened and then closed. If, however, the valve starts to chatter slightly, indicating a loose rubber, or if no water flows, indicating that the valve is loose on the stem, the hydrant is immediately closed, the water trouble desk is notified and the information is radioed to a field crew for immediate action.

As the volume of water which may flow from this apparatus is very small, only a slight chatter is possible and a quick shutdown can be made. If the hydrant valve is opened too quickly on the first two turns by spinning the wrench, there is a possibility that the volume of water necessary to fill the apparatus will not have had time to accumulate and cause a back pressure on the outside of the valve. This will allow the rubber to slam shut if it is loose. Should static pressure be desired, the wheel valve is closed while the water is flowing, and the pressure is read on the gage.

A similar apparatus, made of 1-in. pipe, valve and hose, is used for testing 4-in. outlets. Fire flow tests on 2½-in. single fire hydrants are conducted using a closed Eddy valve, which is operated after the fire hydrant valve has been fully opened. Fire flow tests on 4-in. double fire hydrants employ the gate valve on the lateral from the main to control the flow. This gate valve is closed, the 4-in. hydrant valve is opened fully, and then the gate valve is reopened and the flow recorded.

Conclusion

A water distribution system such as that of Los Angeles—which supplies many areas through pressure regulators, has many large consumers, maintains more than 25,000 fire hydrants and has in excess of 390,000 active services—must always be alert to the possibility of water hammer. There are 85 permanent seven-day pressure recorders in the system, and the charts are analyzed every week for erratic pressures and unusual conditions.

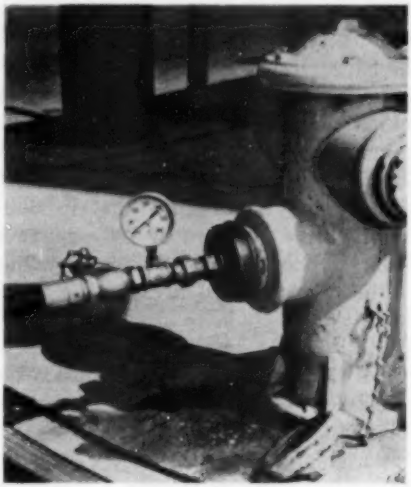

FIG. 2. Hydrant Testing Apparatus

The problem, however, affects all water systems, large and small, and it is hoped that this paper on its practical aspects will be helpful.

Aspects of Competent Purchasing

By H. R. LaFortune

A paper presented on Oct. 27, 1949, at the California Section Meeting, Sacramento, Calif., by H. R. LaFortune, Mgr., Purchases & Stores, Sacramento Municipal Utility Dist., Sacramento, Calif.

A GOOD many years ago the principal tools of the purchasing agent were a rubber stamp and a few catalogs, but this field of endeavor has come a long way since then. World War II established once and for all a definite place for the purchasing profession in business. Considering that, in the National Assn. of Purchasing Agents alone, there are over 13,000 members, one can well appreciate that purchasing has left the rubber stamp stage. The purchasing agent today is a specialist in vendor relations, thereby lending efficiency not only to his own department but to the organization for which he works.

The distinction between "purchasing" and "procurement" should be clearly understood. For purposes of clarification, it may be said that procurement refers only to the obtaining of material, whereas purchasing involves a careful analysis of various factors before placing an order. Profits can result from purchases as well as from sales, and profitable purchasing means buying the right quality and quantity from the right source of supply at the right time and price.

From the beginning it should be made clear that the purchasing department is a service organization. It should not give orders to other departments but, instead, should be a source of information and suggestions, since through its many contacts with vendors and purchasing agents, it is in a splendid position to furnish or obtain the data required by the various departments of the utility.

Quality of Materials

It is generally recognized that the quality of products being used is primarily the concern of the operating or engineering departments of an organization, but the purchasing department also has a definite stake in the matter. It is the purchasing agent's responsibility to learn as much as possible about the use of the products he purchases for his organization and the reasons why the specifications restrict the materials to this or that quality. It is very much his concern if a specification is so restrictive as to preclude a responsible bidder from making quotations and supplying the utility.

The purchasing agent should carefully watch the reorder rate on equipment and supplies, because it may indicate whether the quality is below the standard required for the job. If he would purchase profitably by buying the *right quality*, the purchasing agent should learn, through association with other purchasing agents and visits to suppliers' factories, as well as visits to the plants of other users, what is being used for similar applications.

The factors to be considered in determining the quality of, or specifications for, a product include the service required of it, ease of installation, durability, expected life, efficiency in operation, availability and price. The management should see to it that the purchasing agent sits in on all conferences preceding the drawing up of specifications, because he is in an ideal position, through his contact with many vendors and his analysis of market trends, to recommend or suggest products that are available and competitive, as well as to prevent the writing of specifications that would be restrictive, noncompetitive or uneconomical.

In this respect, the purchasing department of the Sacramento Municipal Utility Dist. has been fortunate in receiving recognition as an important part of the organization, and sits in on "weekly operating committee meetings," which bring together all department heads and the general manager. Purchasing is thus kept apprised of all affairs affecting policy, as well as programs for future development of the district which may have a bearing on future requirements for materials. Supplementing these weekly meetings, the heads of the operating, engineering and purchasing departments confer each week in order to coordinate their activities and keep each other informed on their respective problems.

It is important that specifications be brief and complete, clearly indicating the use to which the product is to be put and providing for a definite method of testing and inspection. The time and money spent in preparing an airtight specification is often wasted through failure to establish a definite procedure for testing and inspecting the product upon receipt. Obviously, this failure works to the disadvantage not only of the buyer but of the more reputable and scrupulous supplier as well.

The purchasing agent should also call upon his supplier for profitable suggestions on how to improve quality, or even reduce it if the utility is buying a higher-quality product than the application requires. Capitalizing on the fact that suppliers and sales representatives are some of the best sources of information, the district now stamps its purchase orders, and particularly its requests for quotations, with the sentence: "The District invites your suggestions for any changes in specifications or other ideas which will result in lowering its costs."

Quantity of Materials

Quantity, like quality, has an important bearing on the profits that may be realized from good purchasing. In determining what quantity to buy, there are certain essential factors which must be considered: the time required for delivery, quantity price differentials, transportation charges, market conditions and price trends, inventory status, storage and interest charges on inventory, obsolescence, and changes in requirements. As in the determination of quality, conferences should be held periodically by the operating, engineering and purchasing departments to study future requirements and possible expansion programs. In this way the purchasing agent is forewarned of future needs.

It has been said that, throughout the United States, industry is generally doing a good job in purchasing but is not so successful in materials management. This term refers to the proper control of inventory in relation to consumption, which, of course, implies purchasing the most economical quantity at the right time. A problem of

this nature confronted the Sacramento Municipal Utility Dist. when it commenced operations on January 1, 1947. The situation was very much like that of a ship setting out to sea with some charts which were vaguely correct and a compass of questionable accuracy. With only an approximate idea of current requirements and no definite knowledge of past requirements which could be related to the future, the first year of operation was hectic at times. To correct this uncertainty, studies were made of the consumption of all stock materials in an attempt to forecast future needs, and this procedure led, eventually, to a complete change in the method of reordering stock materials.

As is common in the water works industry, the replenishment of materials is often based upon visual observation of warehouse stocks. As a result of the studies, however, a procedure has now been established by which purchases are based directly on past consumption. A sizable reduction in inventory has thus been effected, and stocks are daily being brought closer in line with actual consumption. Before the reorder procedure was established, a study was made of the past consumption of each item ordered, including such information as delivery time, standard package quantities and quantity discount brackets. From these data, minimum and maximum inventory quantities were established and a reorder figure (between these limits) was agreed upon. A list of all stock items, with the minimum and maximum inventory quantities, was submitted to the engineering and operating departments for final approval and the procedure was put into action.

If delivery conditions warranted, the maximum quantity was established as a three months' supply, with a minimum inventory of approximately one month. Obviously, delivery time, quantity discount and strikes or threats of strikes must influence, to some degree, the minimum and maximum stocks, but the inventory quantities agreed upon are continually being reviewed and, as stated before, the procedure has resulted in a saving of personnel time and in the elimination of much red tape in the handling of requisitions. For most items, a reorder card is used, which is automatically processed, thus removing the danger of an item being overlooked in the warehouse. The cards are reviewed daily through the use of a "graph-a-matic" * chart. Visual observation of stocks on hand has shown the effectiveness of the reorder card system.

There are other advantages to this system. Specifications can be typed on the reorder cards, thereby reducing clerical errors and time spent in writing up requisitions. The card also lists all acceptable suppliers of the item in question and furnishes a history of past purchases so that the buyer may avoid placing the order at a higher price. The buyer also has a record of promised and actual delivery dates on previous orders. In addition, the card contains monthly consumption figures, so that any changes are immediately obvious.

In discussing this subject, the problem of slow-moving or obsolete materials cannot be disregarded. Since obsolescence is an important factor, particularly in the electrical industry, the purchasing department submits to the district management a monthly report showing the quantity and dollar value of outmoded items. Before any

* A trade name of Remington Rand, Inc., New York.

new item is added to inventory, the engineering or operating department requesting it might well be asked to provide for the disposal of the materials which it may replace. This practice would help considerably to prevent an inventory of obsolete materials.

Sources of Supply

Profitable purchasing from the right source of supply is one phase of activity in which the purchasing department may definitely prove its worth as a service organization. All of the economies that may otherwise be effected will be lost if a supplier in whom confidence has been placed fails to produce the necessary item at the required time. Establishing proper sources of supply is certainly one of the most important functions of purchasing and requires the purchasing agent's most careful study. Before establishing a source of supply, the following steps are recommended:

1. Check with other buyers or the local purchasing agents association for recommendations on good sources of supply.
2. After selecting several sources, have the credit department examine their financial status.
3. Decide how much of the utility's business it is desirable for a single supplier to have. It is important that purchases should be neither too concentrated nor too dispersed.

In making a careful selection, the purchasing agent should visit the suppliers' plants whenever possible, study their operations and learn their problems. By so doing, he may find a peculiarity in the utility's own specifications which requires special treatment by the supplier, resulting in higher prices. The purchasing agent should know the total production figures for the material in question and what percentage of that total is the supplier's share. If there is a trade association for suppliers of the particular material, the purchasing agent should learn what its price policies are.

In addition to the financial status, the financial report on the supplier may also indicate whether the firm is affiliated with another source of supply.

In locating sources of supply, the purchasing agent can make use of his own records; information obtained from the National Assn. of Purchasing Agents or local affiliated associations; various business directories (1–5), catalogs and trade journals; railroad freight data; chambers of commerce; and direct contact with the vendor.

While discussing suppliers, some thought should be given to supplier-buyer relations. Close cooperation between salesman and buyer is important to both parties. It is highly questionable whether the purchasing agent should receive favors from salesmen, but, if the purchasing agent takes the salesman out to lunch now and then, it certainly should not hurt the friendly spirit that ought to exist between them. In this connection, there is no more reason why a salesman should send a gift to the purchasing agent than the other way around. Both are doing their jobs to the best of their ability and a gift seems superfluous and unnecessary. The district has therefore politely requested suppliers not to send presents to its employees.

Special visiting hours for salesmen should be avoided. When one calls, he should be received promptly and courteously, and the interview should be concluded in a reasonable length of

time. If it is difficult for the salesman to see the purchasing agent or his staff of buyers, the salesman's time is less efficiently used, which will ultimately be reflected in the cost of that company's products.

Timing of Purchases

Sufficient quantities of material must be on hand when required, and, if possible, purchases should be so timed that any fluctuation or seasonal variation in price will be to the advantage of the buyer. The purchasing agent must, to the best of his ability, be in a position to forecast prices and price trends, as well as supply and demand relationships. He must study markets and financial trends, government regulations and manipulation of prices, wages and price levels, and he should continually be on the lookout for better and cheaper materials, in addition to better sources of supply.

If material must be purchased at the price in effect at the time of shipment, a deescalator clause should be inserted in the agreement, stating that the price quoted will be the maximum and any reduction prior to shipment will be passed on to the buyer.

It must be remembered that no saving or improvement made through timely purchasing will be justified in the eyes of management if the materials are not on hand when required. As a service organization, one of the first objectives of the purchasing department must be to have what is needed where and when it is needed.

Price Considerations

The question of price has been left for the last because, unfortunately, price is too often given prime consideration, with the result that quality, service and other aspects are overlooked. There is little gained from purchasing at a superficially cheap price to the detriment of the quality and life of the product. At present labor charges, replacement of equipment and materials is indeed costly, and careful thought should be given to the rate of replacement (because of poor quality) of one product compared with another.

Competition is the life of trade, and, in the author's opinion, competitive bids should be obtained before a purchase order is issued. It is fallacious, however, to consider price, by itself, as an indicator of quality. It must be remembered that a high price may show that a supplier is inefficient in operation, that his overhead expense is too great, that he spends too much on advertising or that he is not competitively located.

Centralization of Purchasing

From the foregoing it can be seen that purchasing must be given an important place in an organization if it is to operate to the best of its ability. If management expects the best from the purchasing department, it must centralize all purchasing responsibility in that department. Decentralization only undermines its effectiveness.

According to a report (6) issued by the National Industrial Conference Board in 1948, it is generally recognized that centralizing responsibility for purchasing in one department [1] tightens control of buying activities and permits their coordination; [2] aids standardization of procedures and performance; [3] allows production, engineering, sales and other executives to concentrate attention on their own jobs; [4] permits employment of buying specialists who know materials,

markets and procedures; and [5] makes it possible to integrate procurement activities with closely related functions, such as storekeeping.

That management is beginning to realize more and more the importance of centralized purchasing is shown by the fact that 34 per cent of all purchasing department heads now report to the company's president and another 38 per cent report directly to vice presidents.

Summary

The advantages of competent purchasing have been well summarized in the National Industrial Conference Board report (6): "A competent purchasing department, properly backed up by management and with the sincere cooperation of other departments, can make a valuable contribution to the company's progress. It can reduce material costs by buying from the proper sources, at the right time, in economical quantities. It is in a position to help maintain quality of product by procuring materials which will exactly fill specific needs. It can also assure a continued flow of needed materials to meet production requirements, while at the same time keeping inventory carrying costs at the lowest level consistent with safety.

"A progressive purchasing force can promote good will for the company in its contacts with other concerns. It can reduce production costs by encouraging criticisms and suggestions from vendors. It should continually put production and engineering executives into contact with new products and sales representatives with profitable ideas. Finally, an efficient purchasing department can contribute to the formulation of general company policy because of its access to up-to-date information on market trends, general business conditions and the supply outlook."

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The California Water Plan

By William L. Berry

A paper presented on Oct. 27, 1949, at the California Section Meeting, Sacramento, Calif., by William L. Berry, Sr. Hydr. Engr., Div. of Water Resources, Dept. of Public Works,, Sacramento, Calif.

IN the spring of 1948 a portion of California suffered severe rationing of electrical power, largely as a result of unseasonable drought. One of the important metropolitan areas of the state is today escaping a disastrous water shortage only because of the fortuitous and timely arrival of Colorado River water through a newly constructed aqueduct. The use of water has been rigidly restricted in several California cities. Many ground water basins are heavily overdrawn, some to an extent which threatens their contamination and permanent impairment, with consequent great economic loss to agricultural and municipal enterprises dependent on them. Recurrent droughts and the unprecedented growth of population and industry have combined to demonstrate once again that water is the most vital and most limiting resource.

California is faced with the urgent necessity of examining the nature and adequacy of its water resources, and of planning to meet future requirements. Public agencies—federal, state and local—recognize the importance of the problem and are vigorously attacking it. This paper will briefly outline the progress of current investigations and planning on the part of the state toward the eventual solution of California's water problems.

Prior Studies

Because they are related to present water resources investigations, it is advisable to review briefly certain past efforts of the state to solve its problems of water conservation, control and utilization. In 1921 the "California Water Resources Investigations" were initiated under legislative authority, and further investigations were authorized in 1925 and 1929, and were carried out under the direction of the state engineer. The resultant report to the 1931 legislature summarized water resources and requirements throughout California and presented and justified the "state water plan." The plan consisted of a number of projects which in the aggregate constituted a coordinated program for conservation, control and utilization of the water resources of the state, capable of development and construction by units, and of variation as necessity dictated.

Several major features of the state water plan have already been implemented. These include water conservation and flood control works in the Santa Ana River Basin, diversion and transmission of Colorado River water to the South Coastal Basin for the Metropolitan Water Dist. of Southern California and its distribution there for municipal use, and the Central Valley

Project for coordinated development of water resources present in that area.

Need for Further Planning

Although investigations leading to the formulation of the state water plan were conceived as comprehensive and statewide in nature, they were never fully carried out. All phases were not considered for certain areas of the state, and important projects were omitted and left for further study. Moreover, although adopted by the legislature in 1941, the state water plan was actually formulated in 1931 and based on investigations and studies conducted in the 1920's. Since 1931 the population of California has nearly doubled, and the need for flood control, conservation and power has pyramided. The dams, canals, power plants and flood control works, which Californians regard with justified pride, are often inadequate even for present requirements.

By 1947 the need for a review of the state water plan was apparent. The legislature, in recognition of this fact, and acting upon recommendations of the State Water Resources Board, provided funds for the program of statewide water investigations now being conducted by State Engr. Edward Hyatt and his staff. These investigations, under the direction of the State Water Resources Board, have as their objective the preparation of a plan for the full conservation, control and utilization of California's water resources, both surface and underground, to meet present and future water needs for all beneficial purposes and uses in all areas of the state, insofar as practicable. This plan, since it is to be of truly statewide scope, has been designated the "California Water Plan."

Present Investigations

The statewide water investigations involve three general study phases: inventory of water resources; determination of present water use and ultimate requirements; and, finally, development of the California Water Plan to meet those requirements. It is planned to present the results of the investigations in four printed bulletins.

Bulletin No. 1, entitled "Water Resources of California," will include tabulations of natural runoff at 300 stations, covering approximately 90 per cent of the total runoff of the state for each season during the 53-year period 1894–1947. It will also set forth the 53-year calculated means for the remaining 10 per cent of unmeasured runoff. These studies, and a plate showing the locations of gaging stations and drainage boundaries within the state, together with a preliminary draft of the text describing methods used in determining unimpaired runoff, have been completed. A tabulation of precipitation records for Bulletin No. 1, at 1,500 stations for the 53-year period, a draft of the explanatory text and eight accompanying plates, including an isohyetal map of the state showing the distribution of precipitation, have likewise been completed. Flood frequencies at 150 locations on principal streams have been determined, and accompanying plates for the bulletin have been made for about 95 per cent of the locations. An inventory on the quantity and quality of sewage effluent and industrial waste water from major sources exported to the ocean has been completed for the San Francisco Bay area and is about three-fourths finished in Southern California. Work is under way on a statewide study of the

inherent chemical characteristics of surface and ground waters. Field and office work on the inventory of water resources was to have been completed by the end of 1949 and it is contemplated that Bulletin No. 1 will be published shortly.

Investigations and studies for Bulletin No. 2, a determination of present water utilization and ultimate water requirements throughout California, are approximately half completed. This work includes the collection and compilation of data on land use and culture for present and potential water service areas, embracing about 40,000 square miles, supplemented by field surveys in those areas where information is inadequate or not available. Because of the importance of the three great urban centers, the San Francisco Bay, Los Angeles and San Diego metropolitan areas, special surveys and studies are being conducted there to determine present water utilization, supplies available under existing water rights and developments, and probable ultimate requirements for agricultural, domestic, industrial and other beneficial uses. Studies of ultimate water requirements involve the evaluation of potentialities for water utilization in areas not now under water service, and of present deficiencies in areas with inadequate supplies. They include projections of present use patterns to the ultimate and determination of water consumption factors for each type of culture. Full use is being made of existing planning data compiled by public planning agencies throughout the state.

Bulletin No. 3 will present and justify the elements of the California Water Plan necessary to meet the requirements outlined previously. Toward this end, preliminary reconnaissance and geological examinations are being made at 150 dam and reservoir sites which are presently under consideration. Approximately 40 per cent of this work has been completed. A number of these sites have also been surveyed, and field reconnaissance is under way to determine other potential sites. Location surveys have been run for possible conduit routes from the Sacramento–San Joaquin Delta to the East Bay area and Santa Clara County, and for an extension of the Contra Costa Canal to the Pinole-Richmond area. Paper locations and field reconnaissances of various canal routes have been made, including a project to divert an ultimate water supply to the west side of the San Joaquin Valley, and a multiple-purpose project to effect complete flood control, water conservation and drainage in the Tulare Lake Basin. Data on hydroelectric power for most of the Sierra and north coastal streams have been collected from previous studies and reports. Detailed power studies have been initiated on the north coastal streams, including geologic investigation of potential dam sites. Plans presented in Bulletin No. 3 will consider the results of studies, now under way, on methods and costs of treatment to reclaim, for agricultural and industrial purposes, the sewage effluent and industrial waste waters presently exported to the ocean. The projects of the California Water Plan will also consider water quality problems and their solution.

It is contemplated that Bulletin No. 4 will constitute a summary report on the earlier bulletins and a restatement of the California Water Plan. If the present tempo of the statewide water investigation is maintained, this final

bulletin should be published during the fiscal year 1951–52.

Supplementing the statewide water study, cooperative investigations are being conducted, pursuant to agreements with local agencies, in areas where special problems require immediate, detailed examination and early solution. Such investigations in the counties of Sutter, Yuba, Monterey, Santa Cruz and Santa Clara, and in the Calaveras River area in San Joaquin County, are nearing completion. Investigations in Livermore Valley, the Mokelumne River area and Lake County will be completed in 1950. An investigation in Placer County is planned for completion in 1951, and steps have been taken by local interests to initiate similar studies in southern Alameda County and in the Farmington area in San Joaquin County. In addition, the Div. of Water Resources is conducting special investigations of the mountainous areas of the state and of the Santa Ana River Basin, both of which are coordinated with the statewide investigation. One portion of the statewide water study, which is being conducted cooperatively by the U.S. G.S. Ground Water Branch, is a determination of the geologic features of ground water basins, including underground storage capacity within economic pumping lifts. Detailed studies are being made of those ground water basins of the state where little or no such work has been done in the past.

Since it relates to the preservation of water resources, mention should be made of recent legislation on the control of water pollution. Legislative acts of 1949 vest control of water pollution in nine regional and one state board. The regional boards, consisting of five appointed members, have broad advisory and coordinating powers and may prescribe and enforce requirements relative to any condition of pollution or nuisance, existing or threatened. The state board, made up of nine appointed members and four state officers, including the state engineer, allocates funds, provides loans and formulates statewide policies. Among the state agencies charged with specific responsibilities under the legislation is the Div. of Water Resources, which is directed to investigate, report and make recommendations on the quality of waters, reclamation of water from sewage or industrial wastes, minimum standards of well construction and damage to ground waters caused by defective or abandoned wells. Drillers are required to file well logs and other data pertaining to new or reconstructed wells. The state has thus recognized the threat of water pollution and assumed responsibility for maintaining the quality of its water resources.

Objectives of Plan

The California Water Plan must provide for all the known uses of water—navigation, irrigation, municipal and industrial supplies, hydroelectric power, mining, recreation and preservation of fish and wildlife—as well as for the preservation of water resources through the control of floods, soil erosion, salinity and pollution. The plan must include multiple-purpose basin and transbasin developments, involving complex problems of many kinds—technical, financial and legal.

In brief, it may be said that California's water problem is twofold, involving, first, the conservation and utilization of water resources, and, second, the control of floods. The problem of flood control is important in all sections of the state, and its solution

requires the construction of detention reservoirs, levees, revetments and bypass channels. Conservation and flood control works can often be combined, but a complete solution of the problem of flood control may require separate works in addition.

California's water conservation and utilization problems are chiefly geographical in nature. By far the larger part of the supplies are found in the north, while the great demands—agricultural, industrial and municipal—are in the central and southern portions of the state. It is apparent that the solution lies in the transportation and exchange of water, generally from north to south, and that the plan must include the construction of surface storage reservoirs and the utilization of the great ground water storage capacity of the valleys for regulating stream flow. Conduits, pumping plants and distribution systems will be required, and incidental features of the plan will provide for the development and transmission of hydroelectric power for project purposes and to help meet the growing demands of the state. Conservation features will in themselves furnish a substantial measure of flood control, as well as salinity control, improvement of navigation, recreation, support of fish and wildlife and other beneficial uses.

It is contemplated that the California Water Plan will provide a solution to the major water problems of each section of the state. There is some speculation at this time on the adequacy of California's water resources to meet future needs. The federal government is presently conducting a preliminary investigation to determine the feasibility of bringing water from the Columbia River to supplement California's supplies. Although the statewide water investigation is only partially completed and the California Water Plan has not yet been formulated, the inventory of water resources and estimates of ultimate requirements so far made indicate that adequate water supplies can be developed from the state's water resources—including California's rights in the waters of the Colorado River—and regulated in available surface reservoir sites and in ground water basins to meet the probable ultimate requirements without resort to importation from the Columbia River.

Tennessee Rate Changes Since 1947

By Charles L. Crangle

A paper presented on Nov. 1, 1949, at the Kentucky-Tennessee Section Meeting, Lexington, Ky., by Charles L. Crangle, Acting Director, Div. of State Planning, State Planning Commission, Nashville, Tenn.

IN the fall of 1947 the Tennessee State Planning Commission surveyed a majority of the cities and towns of the state to determine the rates and charges currently in effect for water, sewer and garbage collection service. A second study (1) of a similar nature was undertaken in 1949. These surveys were in line with other fiscal studies in the field of public works which the commission's Div. of State Planning has from time to time undertaken in order to aid Tennessee municipal officials with concrete, overall data on municipal facilities.

Findings of Survey

The 1947 study was an interesting one, particularly from the standpoint of the data obtained on municipal water rates. This was the first comprehensive study that had ever been made of such municipal charges in Tennessee, and one of the first in the United States. The report demonstrated that, in theory, few Tennessee communities charged adequately for the water service they were rendering. Although national experts in the field of water rates, for example, agreed that the cost of supplying 2,500 gal. to a customer in a community of under 1,000 population should average from $3.00 to $3.50 a month, in Tennessee the average bill was only $1.74, with rates ranging from $1.00 to $2.75 a month for the same population bracket.

It was recognized that water service should become increasingly cheaper as larger populations were served, but, over the entire range, rates varied little among the communities of the state and were remarkably low. A number of explanations of these low rates have been advanced; perhaps the most pertinent, aside from failure to consider the cost of service, are, first, that many of the systems had been constructed more than 20 years before, at a time when costs were much less than in 1947, and, second, that a number of the plants were built during the depression years with federal aid from the WPA and PWA, the federal government financing up to 45 per cent of the total cost. Tennessee municipal water bills often, therefore, did not represent a need to pay off any sizable bonded indebtedness. A third possible explanation is that few water systems were found to have set up any fund to care for depreciation or deferred maintenance despite already rising costs. Attention was called in the report to the fact that the 1947 reproduction cost of most of the systems discussed would have required rates more than double those effective at the time.

In 1947 there was evidence that, during the war years and their immediate

aftermath, little in the way of improvements and extensions to Tennessee municipal water systems had been undertaken. The 1947 report further indicated, therefore, that increased costs of such improvements would have to be taken into consideration in future years.

The remarks made above would seem to imply that Tennessee municipal water rates in 1947 had been static for a number of years and had failed to reflect rising costs. Yet, surprisingly enough, the majority of the rates studied were only about ten years old. While 56 per cent of the reporting communities had rates established prior to 1941, only 16 per cent were employing rates which had become effective prior to 1929. Consequently, it might be said that in 1947 Tennessee municipal water rates were generally not too far behind the times chronologically, but years behind from the standpoint of good business administration. The State Planning Commission's 1947 report on municipal water charges closed with a plea for careful study of water rates by the operating municipalities and the adoption of such increases as seemed necessary to meet the increased costs of current service.

So much interest was manifested in the 1947 report, both within and without the state, that it was decided early in 1949 to revise the publication. Accordingly, every water system in the state was again queried, and the revised report was published in October 1949 (1). It is now possible to make certain comparisons which chart the changes in Tennessee municipal water rates that have come about since 1947.

Rate Trend

Generally speaking, either as a result of the advice given in the earlier report or in response to the conditions it forecast, Tennessee municipal water rates have risen during the period 1947–49. Sometimes the formula for the increases was quite obviously based on the supposed public attitude rather than on the actual revenue needs of the water system. The increases have, however, been halting, evidently undertaken only when forced upon municipal officials by the pressing need for revenue and then probably not nearly great enough. Since the rates generally increased all along the line in about the same proportion, regardless of population size, the variance among the entire range of rates remained approximately the same as in 1947. In a few systems, the water rates were actually decreased during this period.

In a number of systems, the increase in rates has been quite marked. New systems put in operation since 1947 have found it necessary to charge rates much higher than those generally prevalent among the older ones. For example, the town of White Pine, with a population of approximately 500, formally opened its water system in April 1949. The supply comes from a well, and treatment is limited to chlorine disinfection. The minimum bill is $2.50 for 3,000 gal., the next 3,000 being billed at 60¢ per 1,000, the next 5,000 at 50¢ per 1,000 and the balance at 40¢ per 1,000. Of 60 other Tennessee communities in the same population bracket as White Pine, only two reported minimum charges equally high, and not even these two communities had above-minimum rates nearly as high as White Pine's.

The rate schedules of municipally owned water systems in Tennessee are not under the supervision of any central state agency, although the state

health department has a measure of authority over the operation and maintenance of the water plant. Privately owned water systems, however, come under the jurisdiction of the Tennessee Railroad and Public Utilities Commission, and their rates can be altered only by action of this state board after a public hearing. Petitions to this agency during 1949 would indicate that private water companies—which have all the problems and difficulties of publicly owned utilities—are well aware that they cannot continue to operate in a businesslike manner and produce even a token profit under the rates effective before the war. Accordingly, a number of the privately owned systems have asked for general increases in their rate schedules, and the commission has usually found it necessary, in simple equity, to grant the requests. The privately owned water system, like other public utilities in private hands, cannot simply close down when operation is unprofitable; on the other hand, few owners of such systems can afford to keep them in good operating condition and make the necessary extensions without additional funds.

In one case heard by the utilities commission in 1949, it was demonstrated that a small water company serving approximately 400 homes had suffered a net loss of more than $1,200 during the past fiscal year. Moreover, the sale of taps and other income in addition to that from normal operations happened to be unusually large during 1948. Had it not been for this extra income, which could not be expected to continue at such a high level, the net loss would have amounted to very nearly $2,500. The owner of this system is understandably anxious to be relieved of the burden and has offered to make a gift of the system to the municipality, but, because the community is unincorporated, the chances of thus solving his dilemma appear remote. There is, of course, little sale value in such a financial millstone.

Just as privately owned water systems are expected to show a profit, so municipally owned systems should at least make sufficient money to pay their own way, a condition which is met less often than it should be. A number of municipal water systems, the author is convinced, manage to continue in operation only because they are subsidized from the general funds of the community. No private business could manage to get by in this manner.

Need for Review

The planning commission's two studies in the field of Tennessee municipal water rates have demonstrated one need above all others—the necessity for a general review of the administration of local water systems. A number of municipal water rate schedules definitely need to be increased if the systems are to meet higher operation and replacement costs. Many water plants which formerly made sufficient profit at their old rates to pay for both depreciation and expansion now find that, with the upward swing in the cost of materials, labor and normal maintenance, the profits have either greatly decreased or else become completely nonexistent. The majority of citizens, and a good many city officials as well, fail to realize that a safe margin of funds for replacement and new construction no longer exists in most municipal water systems. It is usually a shock, when new construction or major repairs become necessary, to discover that all available funds have been

used up in normal operations and that there is no excess to help meet the contemplated new expenditures.

The best method of expanding and improving municipal water systems is, of course, through the use of current revenues or accumulated funds. This procedure is only about half as expensive as issuing bonds to finance the same amount of work, but few, if any, Tennessee municipalities have reserve funds for such purposes today. As a result, a large number of municipal water bond issues, both of the revenue and of the general-obligation type, have been sold in this state since the end of the war.

It is important to realize that the average interest rate on municipal bonds has been steadily increasing since 1946 and that it is now more than twice what it was in the spring of that year, when interest rates on municipal bonds reached their lowest ebb. Because of this rise in interest rates, the financing of water works improvements is further complicated; such financing must today contend not only with an increased cost of materials and labor, but with the increased cost of borrowing money as well. Higher water rates at the present time, with the resultant possibility of putting aside a water works reserve fund for future improvements, will make unnecessary at least some municipal water works bonding in future years. Had such funds been accumulated in the past, many water departments would not now be saddled with heavy bond issues.

Among other important reasons for considering municipal water rate increases at the moment is the heavy growth of urban population. Tennessee is an expanding state industrially, and there is every indication that its municipal population is growing in proportion. It must be realized, however, that this new population growth is not likely to be in the older sections of communities, where adequate water lines are already provided. Rather, the population rise will usually be found in newly developed suburbs which require the extension of municipal water lines. The result of population increases, therefore, means more operating expense for the water works, as well as a heavy capital investment at a period of top construction costs.

Additionally, the increased industrial progress of Tennessee has led to demands for more uniform types of water with more constant pressures, and often for enlarged distribution and storage facilities. All of these factors have increased the cost of water service to such a degree that the older rates are no longer able to supply the required revenue.

There are undoubtedly a number of municipal water systems which require good administration more than they do any rate increase. It should be recognized that inefficiency in plant operation and poor record-keeping can run up the cost of municipally produced water, and in turn make higher rates necessary. This unfortunate sort of operation can be corrected by competent local officials, and the possibility of such loss of revenue should at least be explored before real attention is turned to the idea of increasing rates.

Diversion of Funds

Water rates often need to be increased, too, because of the practice of diverting water revenues into the municipal general fund. Although this practice has been condemned for a long time, it is the rule rather than the ex-

ception. This situation must be faced in discussing water rate changes. Many new rate schedules have gone into effect in Tennessee during the last couple of years because the municipality needed additional revenue and water department funds were an easy source. Fund diversion is so hidden behind a smokescreen of debits and credits that it is seldom recognized for what it is. Frequently municipal officials will not admit in so many words that water rates must be increased in order to give them additional money with which to run the city. Instead, the usual practice is first to divert as much of the water department funds as possible. Then, since no money remains in the departmental treasury to pay for extensions and other improvements to the system, it becomes obvious to all that, if these improvements are to be made, they will have to be financed, and financing means increasing the water rates.

Some will say that it really makes very little difference whether the citizens pay the cost of running their city government from the property tax or by way of the water bill. It seems to the author, however, that it is time the citizens grew up; if they believe it more painless to pay for city government through water rates, well and good—but let the fact be publicized and let them recognize what their money is going for. All sorts of items are attached to water bills today. In one city an overall hospitalization plan was financed by adding the charge to the water bill. If the practice of hiding the additional cost of city government beneath the label, "Monthly Water Bill," were stopped, a number of municipalities would not need to increase their present water rates.

Conclusion

In Tennessee, as in most other parts of the nation, there has been a recognizable tendency toward increasing municipal water rates since the end of the war. For possibly a majority of the systems, this increase has been necessary because of the increased cost of operation and maintenance and the rising demand for additions and extensions. On the other hand, the rates of many systems might have remained at their former level had economy and good operation been faithfully practiced. Again, a number of rates were probably forced upward because of the increased diversion of local water revenues by various municipal governments.

Municipal water rates are climbing generally all over the country, in line with the trend for most other commodities. But, after careful study of Tennessee municipal water rates and of the rates of a large number of cities throughout the nation, the author has concluded that water is still about the cheapest municipal service which the citizen gets.

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Elements in the Rate Structure

By Merrill L. West

A paper presented on Nov. 1, 1949, at the Kentucky-Tennessee Section Meeting, Lexington, Ky., by Merrill L. West, Chief Operator, Water Purif. Plant, Kingsport, Tenn.

IF a dozen men were given identical data on a newly designed water system and asked to develop a rate structure, no doubt twelve different schedules would be submitted. One reason for this variation would be that the actual cost of the water produced and delivered could not be known until the plant was in operation. When a water system is provided for a community which previously has not had a public supply, it is, of course, necessary to establish rates based on experience and good judgment. If the revenue is sufficient to meet expenses, the rates thus set frequently remain unchanged even though they may not remain fair or sound.

Most water works officials, however, do not have to start with a new system, but have the advantage of knowing approximately what the annual requirements will be, in both water to be supplied and expenses to be met. Perhaps the word "advantage" should read "disadvantage," as these men frequently see the expense total rapidly approaching the revenue total and wonder if increased rates will be necessary to keep the red ink off their ledgers. That such a condition is not unique is indicated by the fact that more than 50 Tennessee communities have revised their rates in the last three years (1). If a change of rates appears necessary, it is most important to examine not only present and anticipated costs and income, but also the possibility of changing the methods of bringing in revenue.

There are two common ways of charging for water: by flat rate and by metering. The former is practical where a large and economical water supply is available—for example, a large spring requiring no treatment and so located that it furnishes a gravity supply to the town. A very small system may also find it more economical to furnish an excess of water than to install and operate a metered system. These instances are few, however, and for most systems metering is the only logical way to charge for water.

An additional source of revenue for systems which provide fire protection is a charge for this service paid by the city to the water utility. Although as much as 50 per cent of the cost of the distribution system may be for fire protection, it is difficult for a municipal system to collect charges in proper proportion. A recent study (2) of five municipal supplies in New Jersey shows that only 1.6 per cent of revenue is derived from fire protection, whereas private supplies in five other communities received 13.5 per cent for this service. The water department which needs additional revenue will probably have to look elsewhere for most of its increased income.

Rate Steps

As most systems have to depend on revenue from metered water, it is essential to consider the meter rates. The principle of lower prices for large quantities of almost any commodity is well understood. Even children know about "the large economy size," whether it is breakfast cereal or toothpaste. The water works field should be a prime example of this trend because of the large capital investment required, with consequent high fixed charges, as against the low cost of processing, measuring and delivering the actual commodity. A sliding scale of three or four steps is usually all that is required—consumption being classified as "domestic," "commercial," "industrial" and, possibly, "wholesale."

The practice in many cities of having ten or twelve steps in the rate schedule seems to be unnecessary. One example is a community where 12,000 gal. of water costs $5.84. Eleven different steps were involved in computing this figure. If the nine intermediate steps were removed, the cost of the 12,000 gal. would be $5.30, or a drop of only 54¢.

It is generally accepted that an equitable rate structure is one in which each class of customer pays for all the costs of the water served to that class. No group should be overcharged or served at a loss. It is also generally agreed that at least three types of costs should be collected from each customer, represented by a service charge, a demand charge and a cost-of-water charge.

The service charge should be divided equally among all customers, since each connection, regardless of size, requires individual meter reading, billing and collecting.

Demand Charge

The "demand" or "ready-to-serve" charge is variable, depending on the requirements of the individual customer. If he has a large service connection, he, in effect, ties up a certain percentage of the system's capacity, even though most of the time he uses only a small amount of water. Ordinarily the utility collects this demand charge by establishing minimum monthly rates for each size of meter in use, the rates increasing sharply for the larger sizes.

Some do not consider a demand charge necessary in the water works field because adequate storage will reduce the plant capacity otherwise required to meet sudden demands. The following incidents which occurred in Kingsport, Tenn., show that large connections *can* cause heavy demands on a system, whether or not a demand charge is made:

1. A textile mill had its own pumping station and storage tank which furnished water for steam and other uses not requiring filtered water. Whenever the river was turbid, however, it became necessary to switch over to city water, at which time quite a large amount was needed. As the river might be muddy for several days, storage alone would not supply the increased amount required. When the turbidity dropped below a certain point, the mill would use the river supply again and might not call on the city for a month or two.

2. Another factory had its own filter plant, but failure of a boiler cut down steam and power production so greatly that additional water was needed. A large connection to the city main was opened, and water began flowing into the plant at the rate of 2 mgd.

3. A third plant buys industrial water from an adjoining factory but is so dependent on water that it has an additional connection to the city supply. In one instance, the private supply was cut off, and for a short time quite a large volume of water from the city was required. Storage, however, was able to take care of the demand.

In any event, a large connection should not be made if the utility is unable to supply the quantity of water which could be used through that connection, and no customer should object to a demand charge, especially one in the form of a minimum monthly rate.

Cost of Water

Getting back to rate structures, the third element to be considered is the cost of water. Although nearly everyone will agree that no water should be sold below its actual cost, a few hold that special low rates should be established for industries, even to the point of selling below cost, if necessary. The author sees no reason for the water utility, whether private or public, to subsidize industry in this manner. An industry requiring a large amount of water can often furnish its own supply at a lower cost than the utility. If not, it should pay the rate set by the utility.

The best way to learn about the cost of water is to keep an accurate account of the costs of each division in the system. In Kingsport, costs are grouped into eight classifications, both by actual expenditure in dollars and by cost per 1,000 gal. produced. The eight classes are: [1] administration, [2] billing and collecting, [3] debt service, [4] purification and pumping, [5] maintenance of mains, [6] maintenance of distribution system, [7] reading and maintenance of meters and [8] unclassified. The revenue for the year is also expressed in actual income and per 1,000 gal., as is the difference between income and expenditure, which at Kingsport is usually a surplus.

A nine-year breakdown of costs in the Kingsport system shows that:

1. Although total costs have nearly doubled since 1940, costs per 1,000 gal. have dropped about 6¢. This condition is due to the fact that until 1948 debt service costs were dropping both in total amount and per 1,000 gal.

2. The revenue, while doubling in the period under consideration, actually dropped in income per 1,000 gal., indicating an increased use of water per meter.

3. The surplus, or profit, varied from less than 2¢ per 1,000 gal. in 1940 to more than 10¢ in 1947.

In 1947 a $750,000 expansion program was undertaken, financed by serial bonds with a maximum life of 20 years, which meant an increase in debt service of nearly $50,000 a year at the start. Taking the 1946 records as a guide, the increase in debt service would amount to nearly 5¢ per 1,000 gal. Since the surplus in 1946 was more than 10¢ per 1,000 gal., it was evident that the rates in use would be sufficient to carry the increased cost.

It is important not only to know how much the costs are, but also to differentiate between the types of expense. For example, the total purification and pumping costs vary with production, but meter reading and maintenance show no relation to production.

Theoretical Rate Structure

It was of some interest to develop a theoretical rate structure for Kingsport and compare it with the one actually in

use. In planning the theoretical rates, it was decided to total the cost of administration, maintenance, billing, collecting, metering and unclassified expense. This total was divided by the number of meters in the system, to get a monthly minimum service charge. Because these classes of expenditure bear no direct relation to the amount of water sold, it was felt that their cost should be borne equally by all customers.

The cost of water produced was obtained by adding the debt service and the purification and pumping costs. Although the debt service does not bear a direct relation to the amount of water sold, the capital investment increases as capacity is increased, and any rate set must meet this cost. These two expenses, figured in cents per 1,000 gal. and labeled "cost of water," set the lowest rate in the theoretical schedule. The intermediate rate consists of three charges: [1] the "cost of water," already mentioned; [2] the cost of the 2,500 gal. of water supplied for the minimum monthly charge (since no provision was made for the cost of water in that classification); and [3] the cost of all water produced but not sold (that is, the unaccounted-for water).

Based on the revenue and cost figures for 1948, the theoretical monthly bill, established by dividing the selected costs by the number of meters, is $1.10. The actual minimum charge is $1.25 for 2,500 gal. The theoretical wholesale rate, based on the cost of water produced, amounted to 12¢ per 1,000 gal., compared with the actual rate of 15¢.

Finding the intermediate or commercial rate was difficult because, instead of one rate, Kingsport has five for the range of approximately 250,000-gal. between the domestic and wholesale rates. The average cost per 1,000 gal. to the customer in this category is 24¢, based on full usage of water in this range, but a spot check indicates that most of the customers who run over the domestic rate pay about 36¢ per 1,000 gal. for the overage. It was necessary to estimate the total amount of water sold in this range. Since about 30 per cent of the water produced was sold in the commercial range, the theoretical rate for this class is then: 12¢ per 1,000 gal. (cost-of-water charge), plus the cost of the water served to the domestic (2,500 gal. per month) class, which amounts to about 8¢ per 1,000 gal., plus the cost of all unaccounted-for water, approximately 13¢ per 1,000 gal. The total of 33¢ per 1,000 gal. comes close to the estimated 32¢ actually collected from this customer classification.

Some factors which have not been considered are the $5.00 a year fire hydrant charge and the fact that outside-city rates are 50 per cent higher than those inside the city. Moreover, in 1948 the water department began making a yearly payment in lieu of taxes, but this expense can be met easily by the additional income collected from outside customers.

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Costs of Water Softening

By Russell S. Banks

A paper presented on Nov. 4, 1949, at the Ohio Section Meeting, Dayton, Ohio, by Russell S. Banks, Local Mgr., Ohio Water Service Co., Marysville, Ohio.

AS far as is known, no community with a municipally owned softening plant has ever voluntarily returned to a hard-water supply, which seems to be a conclusive argument for the value of softened water. The average consumer using hard water seldom realizes that he is employing a most expensive method of softening, because, before soap has any cleansing action, it must first soften the water. The layman, the water user and bill payer, may believe that water is water and as long as it is clear, safe and plentiful, there is no cause for complaint. Consequently, the average citizen goes on complacently paying soap, laundry, fuel, heating, plumbing, pipe-cleaning, linen renewal and innumerable other bills—all higher than they should be and some entirely unnecessary—simply because there is too much hardness in the water.

It is an easy matter to make out a case for soft water, but it is often difficult to overcome public prejudice, especially when combined with the organized opposition of a small minority which has some selfish reason for not wanting soft water.

Soap Costs

Water employed in the home for washing clothes and dishes and for general cleaning requires the use of sufficient soap to produce good lather, that is, a little more than enough soap to react with the hardness present and effect complete softening. It is probable that, in the average home, only a part of the water used in washing hands and in bathing is completely softened with the soap. Although estimates of the amount of water completely softened with soap in the home vary widely, a typical figure would probably be 4 gpd. per capita, or a total of 5,840 gal. per year for an average family of four.

Checking at several retail stores, the author found that the retail price of high-quality neutral soap flakes was 27¢ for a 12½-oz. package, or 34.5¢ per pound. Retail prices on four leading brands of nationally advertised laundry soaps ranged from 17.7¢ to 19.8¢ per pound, averaging 18.7¢. Although it is difficult, without making an actual survey, to estimate the proportion of hand soap, neutral fine-fabric soap and ordinary laundry soap used by an average family, it appears fair to assume that, with a price of 34.5¢ for fine-fabric soap and a price of 18.7¢ for ordinary laundry soap, the typical family pays an average of 23¢ per pound.

The average hardness of the raw water softened at the Marysville, Ohio, plant in 1949 was 312 ppm., and the

average hardness of the softened water pumped to the distribution system during that year was 92 ppm. Based on C. W. Foulk's formula for calculating the amount of soap required to soften water (pounds of soap consumed per 1,000 gal. of water equals $2 + 0.2H$, with H representing the hardness of the water expressed as parts per million of $CaCO_3$), it would require a yearly total of 268.64 lb. of soap—costing $61.78 at an average price of 23¢ per pound—for an average family of four to reduce the hardness of 4 gpd. per capita of water from 312 to 92 ppm. It would cost this average family an additional $16.65 a year for the soap needed to reduce the hardness from 92 to 40 ppm., the point below which hardness may be ignored as a factor in soap consumption. To soften the water from a raw water hardness of 312 ppm. to the point where the soap starts to have some cleansing action therefore costs the average family of four $78.43 a year.

Cost of Cisterns

In most towns or cities where the hard-water supply is not softened, nearly everyone has a cistern. The houses have dual piping systems, cistern water being used for all purposes except commode flushing or outside sprinkling. Cisterns for soft-water supplies were common until recent years, when domestic water softeners and soft-water services entered the field. Rainwater, collected from the house roof and stored in the cistern, was usualy of poor quality, highly colored, dirty, inconvenient and sometimes hard.

When Marysville, which had previously been supplied with untreated well water having a total hardness of 900 ppm., changed to softened water in the spring of 1929, the cisterns rapidly disappeared from use. To the author's knowledge, not a single cistern is now being employed as a source of soft water.

When figuring the cost of this dual water system, the author can look to his own experience. At the time Marysville still had a hard well water supply, the expense of building a large cistern with a sand filter wall inside to insure clear water was as follows:

250-bbl. cistern	$250
Electric pump	85
Pump installation	20
Extra plumbing	65
Total	$420

With interest at 6 per cent and depreciation at 3 per cent, this extra soft-water equipment cost $37.80 per year, not counting the cost of power.

Cost of Consumer-Owned Softeners

Individual cation-exchange water softeners are used quite extensively in the home, but they are expensive and inconvenient to care for properly. Some plumbers state that the average life of a domestic sofener is as low as eight years, because the householder will not maintain it adequately; he may allow the sand to run to exhaustion and become caked before having it regenerated. In this paper, however, a yearly depreciation of 10 per cent has been assumed.

Records indicate that during 1949 Marysville delivered an average of 105 gpd. to each domestic consumer connection, or a total of 38,325 gal. per year. The amount of water which has to be softened in the average home may vary somewhat, but an average of 50 per cent—19,162 gal.—seems fair.

With a cost of $182 for a 40,000-grain softener plus $50 for installation, and assuming interest at 6 per cent and depreciation at 10 per cent—to which must be added $1.55 a year for the salt required to reduce the hardness from 312 to 92 ppm.—the annual cost of operating the domestic cation-exchange softener would be $38.67 for the average domestic consumer, a family of four. (The salt requirement is assumed to be 0.4 lb. for each 1,000 grains of hardness removed, the present retail price being $1.55 per 100 lb.)

The softened water in Marysville averaged 92 ppm. in total hardness during the year 1949. There is no soft-water service located in Marysville and few consumers own domestic softeners, because the softness of the water is generally satisfactory. For those who have softeners, the annual cost is about $28.28, based on the following figures: price of 20,000-grain softener, $147; cost of installation, $50; interest, 6 per cent; depreciation, 8 per cent; cost of salt per year, to remove 92-ppm. hardness, 63¢.

Soft-Water Service Cost

It is said that, where a soft-water service is available, it is largely replacing the use of consumer-owned softeners. The expense of this service does not differ much from that of operating the consumer-owned softener, while the burden of maintenance is removed from the consumer. The cost of the service is based on the hardness of the water—that is, on the number of times a month the account has to be serviced. The cation-exchange cylinders are of 20,000-grain size, and a cylinder change every 28 days costs $2.50 a month; 21-day service costs $3.25; 14-day, 3.75; and 7-day, $6.25. An installation charge of $10.00 is made. These prices apply to soft-water service in two central Ohio cities having a water supply with a hardness of approximately 340 ppm. In another central Ohio city, where the hardness is approximately 150 ppm., the charge for the 28-day service is $2.50 a month, plus $1.00 for each extra cylinder within the period. In view of the 312-ppm. hardness of the raw water at Marysville, the domestic consumer would probably require the 21-day service, at a yearly cost of $39.

In the two cities having a water supply with a 340-ppm. hardness, several individuals stated that the use of the soft-water service reduced their soap consumption to one-fourth of the amount needed with unsoftened water. The superintendent of the water department of one of these two cities has 28-day soft-water service in his own home, at a monthly cost of $2.50, or $30 per year. Based on an actual record of soft-water soap consumption in his home for a period of three weeks, he found that his annual soap bill came to $17.83, compared with an estimated soap cost of $41.46 before installation of the soft-water service. The saving of $23.63, or 57 per cent, a year in soap cost alone is only $6.37 less than the cost of the soft-water service. In all probability the other savings, such as prolonged life of linens, will more than make up the balance.

Municipal Softening Cost

It is difficult to arrive at an exact figure for the increase in water costs which would be caused by softening the supply at a central plant. This extra expense involves fixed charges for con-

struction; depreciation on the extra equipment used in softening; and operating costs, including chemicals, power, supplies, labor and superintendence. Most of these items will be greatly affected by the size of the plant.

Based on data published by Hudson (1) and Larson (2), and on the author's own experience at Marysville, the extra costs created by softening a water supply with a hardness of 300–340 ppm. would be about 10¢ per 1,000 gal. for the average small treatment plant. If the average family of four uses 3,200 gal. monthly, the extra cost will amount to $3.84 per year. In addition,

TABLE 1

Softening Cost Comparison

Softening Method	Annual Cost $
Soap and hard water	61.78
Cistern supply	37.80
Consumer-owned softener	38.67
Soft-water service	39.00
Municipal softening	4.35

the consumer's share of the cost of free or unaccounted-for water would probably raise this figure to nearly $4.35. These calculations assume that a surface supply is being used and that coagulation and filtration are necessary in any event. Well water softening costs are discussed by Paul C. Laux (*see* p. 399).

Summary

Table 1 summarizes the cost of the various methods of softening water for an average Marysville family of four. All figures are based on a hardness reduction from 312 to 92 ppm.

The savings in soap which result from the use of softened water have been discussed. Other benefits of soft water—such as longer fabric life, lower repair bills for plumbing and water-using equipment, better appearance of dishes and glassware, absence of bathtub rings, and improved condition of cooked vegetables—which are also significant, have been dealt with by other writers, particularly Olson (3).

This paper has attempted to evaluate water softening only from the standpoint of the domestic consumer. Many industries may find soft water necessary or desirable. Furthermore, the water utility will also benefit from softened water—through reduction of meter maintenance cost, for example.

The effect of synthetic-detergent development on the need for soft water is another aspect of the subject which must be given consideration. These products appear to have both drawbacks and advantages. The question of synthetic detergents requires further study, however, before reliable conclusions can be reached.

Although emphasis has been placed almost entirely on the economy of using soft water, its real value lies in the comfort and convenience it affords, and the only way to appreciate these advantages is through experience.

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Discussion

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The author has discussed the cost of municipal softening of surface supplies, which is usually incidental to other treatment processes. When well supplies are being treated, to remove iron and carbon dioxide, for example, plant construction and operating costs (except for chemicals) are not much increased by providing water softening. If the well water could otherwise be pumped directly into the mains, however, all of the cost of building and operating a treatment plant must be charged to water softening. The actual increase in cost per person served depends primarily on four factors:

1. The number of persons to be served.
2. The size of the plant to be built. (The building cost per million gallons decreases as the size of the plant increases.)
3. The amount and character of the hardness to be removed. (In the lime–soda ash method, it is more costly to remove noncarbonate than carbonate hardness. Likewise, it is more expensive to remove magnesium than calcium.)
4. The volume of chemicals purchased. (Price depends on volume.)

If the cation-exchange method of softening is used, the character of the hardness has little bearing on the cost. As the type of softening to be preferred is not under discussion here, it will be assumed that the lime–soda ash method is to be used and that: [1] a population of 7,500 is to be served; [2] the average consumption is 100 gpd. per capita; [3] to allow for emergencies and peak demands, the plant will have a capacity of 1 mgd.; and [4] the hardness is to be reduced from 340 to 70 ppm.

If the designing engineer and the city officials remember that they are building a utility installation, and not a cathedral, the cost of constructing an efficient and attractive plant of 1-mgd. capacity should not exceed $100,000. If interest is charged at 3 per cent and depreciation at 2.5 per cent, the final building cost to the customers would be $5,500 per year.

The cost of chemicals for reducing the hardness of a municipal well water supply in Ohio from 340 to 70 ppm. was recently calculated as 3.5¢ per 1,000 gal., including recarbonation and the use of a polyphosphate. For the sake of simplicity, it may be assumed that the cost is 4¢. Then, if the pumping average is 750,000 gpd., or 275 mil.gal. per year, the annual chemical cost will amount to $11,000. Operational and maintenance costs should not exceed $9,000 or $10,000 a year, provision being made for at least two full-time operators, a part-time operator, low-duty pumping costs and incidental maintenance and repairs. The total cost of water softening would thus be $26,500 a year for 7,500 people—$3.60 per capita per year, 30¢ per capita per month or 1¢ per capita per day.

The author has calculated the cost of obtaining soft water in the home, whether through a cistern, a consumer-owned softener or a soft-water service, to be over $3.00 a month. Obtaining soft water from a municipal well supply

costs $1.20 per month for a family of four.

Synthetic Detergents

It is rather difficult to state what effect the use of synthetic detergents will have on municipal water softening. They are superior to soap in hard water for most household cleansing operations. It seems, too, that, for some purposes (as, for instance, dishwashing), they have an advantage over soap, even in soft water. Their quality will probably be improved and their usefulness increased. A rather extensive review of current literature, however, leads to the following conclusions:

1. Many observers believe that the amount of detergent required in hard water is greater than the quantity used in soft water. This increase is not as great as would be true for soap, but a definite saving in the amount of detergent appears to be indicated if soft water is used.

2. Synthetic detergents are somewhat specific in character. Some brands are better adapted to certain kinds of cleansing processes than others. In short, no synthetic detergent can as yet be termed a universal cleansing agent.

3. Commercial laundries prefer to operate with soft water and soap rather than with soft water and detergents. It is believed that soap works well in soft water on all types of fabrics and all kinds of dirt. According to laundry industry trade papers, no one detergent is equally as successful as soap on all types of fabrics and all dirt classifications. Furthermore, clothes washed in soap seem to iron more easily than those washed in synthetic detergents.

4. Up to the present it has been impossible to make synthetic detergents into bars, and they have not gained much popularity for personal hygiene.

Consequently, it would seem that municipal water softening is still of great benefit to the consumer for cleansing and laundry purposes, either with soap or with synthetic detergents. The actual saving in detergents as a result of water softening should be determined, however, and the other benefits of soft water should be more definitely evaluated.

The Use of Asphalt in Hydraulic Works

By J. M. Lackey

A paper presented on Nov. 12, 1949, at the Arizona Section Meeting Yuma, Ariz., by J. M. Lackey, Dist. Engr., Asphalt Institute, Los Angeles.

THE use of asphaltic mixtures for lining reservoirs, canals and storm channels is a method which has definitely proved successful. Numerous installations in the Southwest, in use from one to 25 years, are still in excellent condition and demonstrate beyond all doubt that asphaltic concrete, when properly designed for the purpose, has the following advantages: [1] It can be submerged in water for many years without deterioration. [2] It can be submitted to daily wetting and drying cycles and still give many years of service life. [3] It can be exposed to desert conditions for many years without noticeable deterioration. [4] It withstands as well as concrete the erosive effect of sand and gravel in storm water. [5] As a construction material, it has splendid resistance to freezing and thawing. [6] It actually holds water—that is, for practical purposes, it can be said to be absolutely impermeable. [7] Its cost is 50–70 per cent less than that of any other construction material customarily used for these purposes. The pages of the *Asphalt Forum*, a quarterly publication of the Pacific Coast Div. of the Asphalt Institute, contain descriptions of many hydraulic works projects in which the advantages of asphalt linings are exemplified (1, 2).

The development of the use of asphalt in hydraulic works, in which the Asphalt Institute has had a leading role, has taken place over a period of 25 years or more. Beside the work done by members of the institute, many engineers with city, county, state and federal bureaus, as well as contractors and equipment manufacturers, have had a part in a vast number of experimental projects using every type of material, mixture and method that could be devised. As a result of this effort, a wealth of technical knowledge and skill is now available to engineers.

It is the purpose of this paper to advocate the use of asphaltic concrete for the lining and facing of reservoirs, canals, dams and storm channels, and the use of buried asphalt membranes for the control of seepage in irrigation canals. It does not advise the general use of other kinds of asphalt linings, such as sprayed membranes, surface treatments or mixed-in-place types, which, though they have received considerable attention and show much promise, are still to be considered in the experimental stage.

Applications

The use of asphalt in reservoir linings in the Southwest dates back 25 or 30 years. Several "mix-in-place" linings (using light road oils) were then employed, followed in the late 1920's by the use of hot-mix asphaltic concrete on several projects (1). At

present two large projects are under construction—the Baldwin Hills Reservoir for the Los Angeles Dept. of Water and Power, which will be lined with nearly 1,000,000 sq.ft. of asphaltic concrete, and a water treatment plant for Brawley, Calif., where more than 500,000 sq.ft. of asphalt lining will be placed.

In 1936 the Los Angeles County flood control agency lined a diversion dike in Hay Canyon with asphaltic concrete and was so well pleased with the performance that by 1944 fifteen erosion control installations on rivers and storm channels had been made. Since that date, additional projects have been completed and two large projects are now in progress.

The paving of highway gutters with asphaltic concrete is a well established practice in certain areas of the state highway system of California. This type of improvement is not to be confused with the method, prevalent in some localities, of lining the gutters with road mixes or cold mixes which do not become tough enough to resist erosion. The type of gutter lining that is giving satisfaction is a hot plant mix type placed with a slip form, which in one operation spreads a uniform amount of material. A heated ironing plate compacts and finishes the course to a smoothness and density comparable to that of the pavement. This method is also used for facing earth dikes at the roadway edge on highway fills. Sometimes the entire dike is constructed with an asphaltic mixture.

During the past ten or twelve years much experimental work with asphalt for canal linings has been done by the U.S. Bureau of Reclamation in Oregon, Washington and Idaho. As a result of the findings, 11½ miles of laterals were paved with asphaltic concrete near Pasco, Wash., in 1947. The paved perimeter of the ditches ranged from 10 to 30 ft., and the total area paved was approximately 87,000 sq.yd. During the same year, as part of the Bureau of Reclamation's California Central Valley Project, a section of the Ignacio Canal (near Concord), 5 miles in length, was lined with asphaltic concrete.

In the Netherlands, it is said, the use of asphalt—generally in the form of an asphaltic sand mixture—for lining canals has been an established procedure for many years. Although the winters in some parts of Holland are quite severe, freezing seems to have little or no effect on the asphalt linings.

Materials and Mixtures

During the experimental years many engineers thought that the processes had to be complicated to be successful, that the perfect combination of aggregate had to be found, that only one grade and type of asphalt would be right, that a specially prepared seal coat would be required and that design and control must be handled by a highly trained corps of engineers. Different organizations have used various types of mixtures with equal success, however. The Los Angeles Dept. of Water and Power has employed street paving mixtures for lining reservoirs with excellent results. Undoubtedly, some of these mixtures are sufficiently porous to permit water to reach the subgrade, but there is no evidence that any harm is done. The Los Angeles County flood control agency generally uses a fine sandy mix with a fairly high asphalt content, which is undoubtedly impervious. It should be pointed out that the Dept. of Water and Power engineers are experts in the construction of dense earth dams, which may

account for their success in the use of porous paving mixtures.

An aggregate grading can consist of a material in which the maximum-size aggregate is between one-half and one-third the thickness of the course. The amount of material passing a 10-mesh screen can vary from 35 to 70 per cent, while the 200-screen material can range from 2 to 14 per cent.

Through long experience, the type of asphalt used has narrowed down to two grades of paving asphalt: 40–60 and 85–100 penetration. Where weed growth is to be expected, 40–60 penetration asphalt should be used, as it is highly resistant to all forms of plant growth. Otherwise, the 85–100 penetration grade is recommended as the best binder.

Some experimental work has been done to determine the amount of asphalt necessary to make an asphaltic mixture impervious to the passage of water. Experiments made in the laboratory of the California Research Corp. indicated that, for practical purposes, properly compacted mixtures would be impervious to the passage of water if the asphalt content was 6½ per cent or more. This rule seemed to hold over a considerable grading range.

Seal coats of many types have been tried, most of them failing to do what was expected of them. Seal coats consisting of air-blown asphalts, asphalt enamels and filled enamels have generally proved total failures. Light-emulsion seal coats have given the best results. It is now the general consensus that seal coats should not be used except to improve hydraulic factors.

The most vexatious problem in the maintenance of asphaltic lining has been due to the destructive effect of mud and algae. Dried cakes of mud and algae found at the water's edge following the recession of the water tend to break up into small octagonal blocks 2–4 in. in diameter, which curl with such powerful effect that small portions of asphalt are lifted from the surface. This difficulty has been entirely eliminated, however, by applying a thin cement wash immediately after completion of the lining. Care should be taken that the cement coating is not heavy enough to form scales, or else all of the cement will come off, leaving the asphalt surface exposed. The cement wash has been found to be quite permanent and it seems probable that it may last throughout the life of the lining without renewal.

Experimental work both in laboratories and in the field has been extensive. A special research department was set up in the U.S. Bureau of Reclamation laboratory at Denver, and eleven technicians devoted their entire time to the problems of the use of asphalt in canal linings. Experimental field installations have been numerous and varied. Constant study has been given to these installations, as well as to hundreds of other experimental projects throughout the West. Gradually, by trial and error and laboratory experimentation, methods and mixtures have been developed and many serious problems solved. During construction processes, new equipment has been devised and perfected and many "tricks of the trade" have been learned. Maintenance problems have also received due consideration and the worst of them have been eliminated by improvement in design.

Durability

Long experience has shown asphalt concrete linings to be sufficiently durable for the purpose intended. Many installations in the Southwest now ten

to fifteen years in service appear to be as sound as the day they were constructed, and there is no reason to believe that they will last less than 25 years. There are several reservoirs in the vicinity that have been lined with a "mix-in-place" type in which an SC–2 road oil was used. After twelve to 25 years' service these linings are still quite sound, indicating that the more durable asphaltic concrete can be expected to have a service life far in excess of 25 years.

Used in storm channels, asphaltic concrete shows excellent resistance to scour from waterborne sand, gravel and boulders. In large reservoirs, there has been no sign of damage from wave action. Asphalt concrete in a sea wall at San Pedro shows absolutely no deterioration from salt water, wave action or any other cause after ten years in service.

Several installations in the Columbia River Basin bear no signs of frost damage although exposed to subzero weather for the past five to ten winters. An examination of the existing installations on western projects showed little or no evidence of maintenance or the need for maintenance, except for the removal of occasional weeds. It may therefore be stated that maintenance costs can be expected to be negligible.

Oxidation

It has been pointed out that asphalt highways when abandoned rapidly disintegrate and that asphalt pavements in desert areas suffer from severe oxidation within short periods. This condition is due to the fact that the percentage of asphalt used in highway pavements is very low, resulting in a state of porosity which permits the penetration of air and the subjection of the relatively thin asphalt films to oxidation. In asphaltic mixtures used in hydraulic works, the asphalt content is from 1½ to 2½ times that of asphalt used in highways. The mixture is therefore very dense and impermeable to air. With the surface exposed to oxidation reduced to an infinitesimal fraction, the oxidation rate can be considered negligible.

Hydraulic Pressure

The very nature of a flexible type of pavement makes it immune to hydraulic pressure. An asphaltic-concrete slab is not affected by temperature and moisture changes in such a manner as to cause the periodic curling and creeping expected from a rigid pavement slab. Gravity causes the asphalt slab to rest tightly on the subgrade at all times under all conditions. Any hydraulic pressure which might develop would, because of the structural weakness of the asphalt and the variability of the pressure, result in minute cracks which would relieve the pressure without material damage to the pavement. No instance of damage to an asphalt lining which could be charged to hydraulic pressure is known.

Costs

The use of asphalt as a construction material has resulted in a most impressive reduction in costs without a material decrease in the quality of the product. Highways paved with asphalt are being constructed at a cost of $2,000 to $60,000 per mile, which is definitely below the cost range of any other construction material used for that purpose. Asphaltic concrete employed in the lining of reservoirs and canals and in flood protection and erosion con-

trol works is making history in the same manner. Asphaltic concrete, when properly designed, is equal or often vastly superior to any other material used for these purposes and construction expense is 50–70 per cent less than for other materials.

Costs for this type of work in Southern California, on jobs of considerable size, have averaged very close to 13¢ per square foot for 3-in. linings. This price includes the subgrade. As a comparable figure, asphalt in streets and highways in the same vicinity, not including subgrade, is bid at an average cost of $4.50 per ton, or about 9¢ per square foot for 3-in. work. Subgrade for ditch and levee construction will cost 2¢–3¢ per square foot, which would indicate a net bid price of 10¢–11¢ per square foot for 3-in. linings, or less than 20 per cent above the cost of street paving work.

Other Types of Lining

Another type of lining which has been used in canals for seepage control is a buried asphalt membrane, described in some detail by J. R. Benson, Bituminous Engr., U.S. Bureau of Reclamation (3). The method consists of overexcavating the ditch 12–24 in. and applying a heavy coat of asphalt. The membrane is then covered with earth or gravel. The only purpose of this type of lining is to control seepage, and a special kind of asphalt that will not be absorbed by the soil in a few years is required.

A considerable amount of research and experimental work has been done on prefabricated linings. These show much promise, and in the very near future it is anticipated that several concerns will be in the market with a low-cost prefabricated lining which can be purchased in rolls and applied by the owner in the field. It is hoped that this type of lining may be produced and sold to the farmer for use in small ditches. The owner would do the work of reshaping the ditch and placing the lining at convenient times, at a total cash outlay of not more than 50¢—70¢ per square yard.

Much experimental work has also been done on prime membrane and membrane types of lining, in which various asphaltic liquids have been sprayed directly upon the earth. These linings are to be considered still in the experimental stage.

A cotton-fabric, reinforced membrane seal is being used as a part of the lining for the Baldwin Hills Reservoir at Los Angeles. It is the first course of a very complicated lining designed for the project and will total nearly 500,000 sq.ft. in area. The seal consists of several applications of hot liquid asphalt, about 1.5 gal. per square yard, finished with a single layer of cotton fabric heavily coated with a filled asphalt enamel. Sections now completed look exceptionally good and may point the way to a new type of lining. Provisions are complete for several trial installations of this type as irrigation canal linings in the San Joaquin Valley.

The "mix-in-place" types have been used with some favorable results in the lining of reservoirs. It is unfortunate that the available data are insufficient for the writing of a specification which would insure constant success with this type of lining. Experience with several projects, in service for from twelve to 24 years, would indicate that a well graded granular material in which the clay content was low—say, not over 6 per cent—and in which rather large quantities of asphalt were used, would

make a very satisfactory lining, although it is not expected that the resistance to weed growth would be very effective. Inspection of the existing projects, however, has shown that the damage from weeds is not very considerable. Linings of this type, 3 in. thick, can be constructed at a cost of 30¢–40¢ per square yard. In desert areas, where the soils are free from clays and organic matter, good results can be expected.

Other Suggested Uses

Asphaltic preparations and asphaltic mixtures can be used to advantage in numerous other installations. Concrete-lined waterways, which may suffer serious structural damage from wear on the invert, can be effectively protected by an asphalt wearing surface. Impressive savings in capital investment can be made by using asphaltic-concrete linings for settling basins, filters, sumps and tanks in sanitary and industrial plants. Asphaltic mixtures are unaffected by most acids, alkalis and brines encountered in industrial and sanitary works.

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APPENDIX

Suggested Design and Specifications

Subgrade

The requirements for a firm, well compacted subgrade for asphaltic concrete linings are no different from those for any other type of lining. Since it is not necessary that soils be of a granular or constant-volume type, however, imported subgrade materials would not be required.

Asphalt Mix Design

It has been pointed out that various mixtures have been used with considerable success. There are certain factors present in different types of construction, however, which would indicate the use of particular kinds of mixtures. In Table 1 are given four mixtures; the coarse mixture, No. 1, is similar to that used for lining reservoirs by the Los Angeles Dept. of Water and Power; mixture No. 3 follows the recommendation of the Los Angeles County flood control agency and is similar to mixtures approved by the U.S. Bureau of Reclamation and the Asphalt Institute for lining canals and flood control channels; mixture No. 2 is also satisfactory for linings and has a shorter curing period than the No. 3 mix; the fourth is a sand-asphalt mixture similar to that used for lining canals in Holland.

The asphalt content given for each mixture in the table will vary somewhat according to the character of the aggregates. An excellent rule to follow, which the author has found reasonably consistent with laboratory results, is based on observation of the shape the mixture takes when deposited in the truck at the asphalt plant, or better, the shape which is attained after the truck has traveled two or three miles.

If the prepared mixture has completely flattened out in the truck, it is an indication that too much asphalt is being used; if the mixture still maintains the shape of a straight-sided pyramid or a truncated cone, the asphalt content is too low. In mixtures of this type, the mass in the truck body should assume a slightly oval shape, with the center of the mix being 6 or 8 in. higher than the edges.

Structural Design

Asphaltic linings, being of the flexible type, are not designed to calculated stress factors but rather to thicknesses which have been found by experience to be adequate for the purpose. For small reservoirs and canals in which the exterior stresses to be expected are inconsequential, a 2-in. thickness is sufficient. In large reservoirs, where much wave action may be anticipated, the thickness should be increased to 3 in. In storm channels which have a considerable gradient and which may carry large boulders and substantial amounts of finer abrasive material, the invert may need to be thickened to 6 in.

The use of reinforcing mesh has generally not been found worth its cost and, in thin linings, has often been found to be actually detrimental. In 6-in. storm channel inverts, however, where the passage of large boulders may occur, the use of mesh reinforcement is recommended.

In the design of ditch linings, sharp corners should be avoided. The intersection of the slope and the bottom should be rounded with a radius of at least 6 in. and as much as 18 in., if possible.

TABLE 1

Asphalt Mixtures for Hydraulic Works

Passing Sieve	Aggregate Grading—*per cent*			
	Mix. No.			
	1	2	3	4
¾ in.	100	100		
½ in.		95–100		
⅜-in.			100	
No. 4	40–56	60–80	90–97	
No. 10	22–32	40–55	65–80	100
No. 40	15–21	25–35	35–45	45–70
No. 80	8–12	18–27	22–30	25–45
No. 200	2–4	6–14	10–16	14–20
Paving asphalt added per 100 lb. of aggregate—*lb.*	5½–7½	7–9	8–10	10–14

Asphalt pavement has been constructed on slopes as steep as 1¼ : 1. It is the consensus of experienced engineers, however, that 1½ : 1 slopes should be the steepest. The past practice has been to curve the top edge of the section back into the bank for 6–12 in., to provide some anchorage and protection to the upper edge. As this procedure has sometimes resulted in a horizontal crack occurring 12–24 in.

below the top edge of the paving, it is recommended that the upper edge be increased to twice the nominal thickness for a distance of 6–8 in., with the inside edge rounded to a radius equal to the nominal thickness of the course. Whenever possible, the top of the lining should not end with a bench, because this can easily become a collector for water which could filter in behind the lining. A narrow bench at the upper edge of the paving also may be used as a trail for livestock, which might cause severe damage to the lining. If possible, the top of the lining should start at least 1 ft. below the top of the slope.

On small projects, it has been customary to use hand methods for spreading and cable-operated rollers for compaction. For large projects, it is recommended that some type of slip form be required. In canals, the forms should be so constructed as to lay the entire section in one operation. When broad revetments or reservoir slopes are involved, construction may be in strips 10–12 ft. in width, placed either horizontally or vertically. In specifying a slip form, it should be described as a piece of equipment which in one operation will uniformly spread and compact an asphaltic mixture to the required thickness and density. Spreading should be accomplished by the use of hoppers and strikeoff blades. The compaction should be obtained by an ironing plate, with the leading edge at the height of the loosely spread material and the trailing edge at the height of the completed and compacted course. The ironing plate should be equipped with a heating device and should be maintained at a temperature higher than the maximum required for the mixture. Density requirements should be 90 per cent relative. If this density cannot be obtained by the use of the slip form, other methods in addition to the slip form should be required.

Other Items

Hydraulic flow factor in canal design. The recommended n factor for asphaltic linings is 0.013.

Seal coat. If a uniformly smooth surface is secured during construction, a seal coat is generally not considered necessary. A light-emulsion seal may, however, be applied to increase the hydraulic qualities of the lining of canals.

Freezing conditions. Where the pavements will be subject to freezing weather, it is recommended that aggregate grading No. 3 be used.

Weed control. If excessive weed and grass growths, willows and tules are to be expected, some provision should be made for their control. The use of soil sterilizers, particularly borax chlorate mixtures, is recommended. It has been found, however, that a dense asphaltic mixture using a hard asphalt in the 40–60 penetration range is highly resistant to all forms of plant growth, and, for a 3-in. lining, it would probably be less expensive to remove the few weeds which penetrate it than to apply a soil sterilizer. This statement is probably also true for a 2-in. lining.

Mud curl. If mud or algae caking is anticipated, the affected areas should be given a cement wash.

Effect of Partial Demineralization of Water on Bacteria

By K. S. Spiegler and Esther Hellinger

A contribution to the Journal by K. S. Spiegler, Water Research Section, and Esther Hellinger, Bacteriological Section, both of Daniel Sieff Research Institute, Weizmann Institute of Science, Rehovoth, Israel.

ALTHOUGH the complete demineralization of industrial waters by means of resinous ion exchangers is being practiced widely and much literature is available on this subject, far less work has been published on the partial demineralization of saline waters for drinking purposes, a process usually applied only in exceptional situations (1, 2). With the general tendency to develop arid regions where many water sources are brackish, however, the importance of the latter problem is increasing.

In the course of a project now under investigation, which is designed to devise and test economic methods of demineralizing brackish waters, the question of bacteriological purity of the treated water arose. It was thought that the acidity of the water resulting from its passage through the cation exchanger might suffice to destroy most microorganisms. Bacterial examination of pilot plant samples showed that, although the brackish raw water contained 100 bacteria per milliliter, the effluent from the cation exchanger column (containing Dowex 30 *) was completely free of bacteria, while the number of bacteria in the effluent from the anion exchangers (containing Amberlite IR–4B †) equaled or exceeded that in the raw water. These observations led to a study of the effect of the demineralization process on bacteria under controlled conditions by following the course of a pure culture of *Escherichia coli* through a sterilized miniature model of the pilot plant. The composition of the water, the flow rate and the regeneration level were made to conform to those customary in the pilot plant.

Experimental Procedure

The apparatus employed is shown in Fig. 1. The length of the columns was 24 and 26 cm., the diameter 3.8 and 2.8 cm. and the height of the regenerated drained resin 18 and 9 cm. for the cation and anion exchanger columns, respectively. The resin columns had previously undergone several cycles of adsorption and regeneration, the cation exchanger having been regenerated only to about one-third of its total capacity in order to effect regenerant economy, while the anion exchanger was regenerated nearly to its total capacity. The cation exchanger was operated solely on the hydrogen cycle.

The flow rate varied from 4.6 to 7.7 ml. per minute (1.4 to 2.3 ml. per cubic centimeter of resin per hour in the cation exchanger and 5.0 to 8.3 ml. per cubic centimeter per hour in the anion exchanger), corresponding to pilot plant rates. It will be noticed

* A product of Dow Chemical Co., New York.

† Made by Resinous Products Div., Rohm & Haas Co., Philadelphia.

that the time of contact with the cation exchanger is longer than is usual in plants employing equal volumes of anion and cation exchangers.

The column feed was prepared artificially to conform to the composition of a typical brackish water of the Negev district in southern Israel, presoftened by ion exchange. Its makeup altered slightly during sterilization. The final analysis (after sterilization) is shown in Table 1.

After downflow regeneration of the cation and anion exchanger with 180

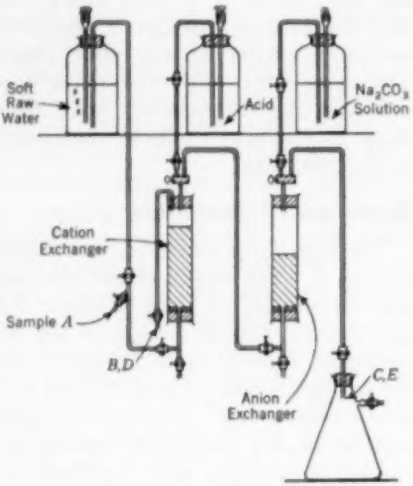

FIG. 1. Arrangement of Laboratory Columns

ml. of sulfuric acid solution (1.52 per cent) and 170 ml. of sodium carbonate solution (3.58 per cent), respectively, the whole model, including the solutions, was sterilized, in separate parts, by heating in an autoclave at about 110°C. for 45 minutes. The anion exchanger column was sterilized by the passage of alcohol and subsequent drying, as the resin is stated to be unstable at high temperatures.

The model was then reassembled, the soft raw water inoculated with 10 ml. of a young, active culture of *Esch. coli* and the purification run started. Upward flow was maintained in both columns. At the beginning, suction was applied for a short while to pass the raw water from the feed bottle into the column. Thereafter the static head proved sufficient to make the solutions flow at the desired rate, which was controlled by means of screw clamps.

Throughout the experiment, every care was taken to prevent, as far as

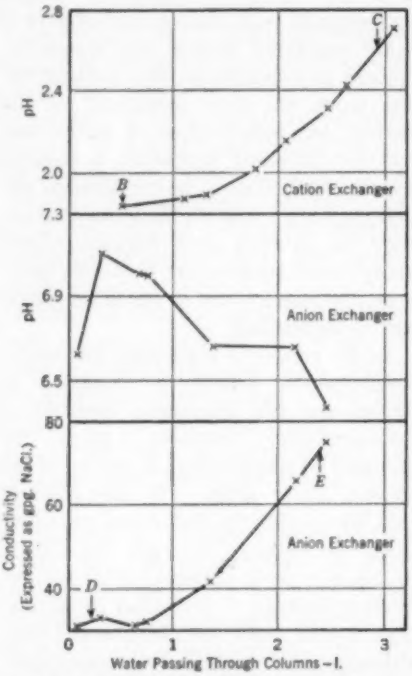

FIG. 2. Effluent pH and Conductivity

possible, the entry of bacteria from the air. About 100 ml. of partly demineralized water was collected before taking the first samples for bacterial examination. All samples for bacterial examination were collected in sterile, plugged test tubes or flasks, and serial dilutions on the media were made immediately after collection.

At the beginning of the exhaustion

run three samples were taken, at the points shown in Fig. 1, from the raw water (Sample *A*) and the cation and anion exchanger effluents (Samples *B* and *C*, respectively). Samples for pH and conductivity measurements were taken at frequent intervals. The pH value was measured by a pH meter; conductivity, by a solution tester calibrated in grains per gallon sodium chloride; Fig. 2 shows the results.

About seven hours later, when the cation exchanger neared exhaustion, as shown by a steep rise in the pH of the cation exchanger effluent and in the conductivity of the treated water, samples of cation and anion exchanger effluent were again collected for bacterial examination (Samples *D* and *E*, respectively).

TABLE 1

Column Feedwater Analysis

Substance	Amount *ppm.*
$NaCl$	1,500
Na_2SO_4	140
$NaHCO_3$	435
Na_2CO_3	10

The initial count of *Esch. coli* in the mineralized water (Sample *A*) was carried out (in duplicate) in serial dilutions in geometric series on lactose broth in tubes. The coliform count of the water during demineralization at the beginning and at the end of the run (Samples *B–E*) was carried out with various quantities of each sample on appropriate amounts of MacConkey's medium in sets of five tubes. All tubes were incubated at 37°C. and examined after 24 hours for bacterial growth and gas production.

Results

Sample A. The initial count of *Esch. coli* in the mineralized water before treatment was found to be 1,000,000 bacteria per milliliter of water.

Samples B–E. Table 2 records the number of tubes out of five showing bacterial growth and gas production from different amounts of each sample.

All tubes showing growth were subplanted on special media and gave positive coliform tests.

Briefly, these results show that, with a count of 1,000,000 bacteria per milliliter in the water before treatment, no bacteria were found in Samples *B* and *C*, less than 10—probably about 4—in Sample *D*, and more than 10—probably close to 100—organisms per milliliter in Sample *E*.

TABLE 2

Number of Tubes Showing Bacterial Growth and Gas Production

Sample Quantity *ml.*	Exchanger Effluent			
	Cation		Anion	
	B (pH 1.8)	*D** (pH 2.6)	*C* (pH 6.6)	*E** (pH 6.4)
	No. of Positive Tubes			
10	0	5	0	5
1	0	5	0	5
0.1	0	2	0	5
0.005	0	0	0	2
0.0005	0	0	0	0
0.00005	0	0	0	0

* *D* and *E* collected seven hours after *B* and *C*.

Discussion

The tests indicate that, at the beginning of the demineralization run, complete elimination of *Esch. coli* occurred in the cation-exchange column and the treated water was free of bacteria. But, when the resins neared exhaustion, a few bacteria, representing a very small fraction of those present in the influent, were transferred to the

anion-exchange column, where conditions were not injurious to them. These statements are based on one cycle only, and the bactericidal action of the cation-exchange step was proved merely for the particular operating conditions described. It is believed, however, that this phenomenon is of a more general nature.

The authors attribute the bactericidal action of the cation-exchange treatment mainly to the acids formed thereby rather than to the specific action of the resin. The less exhausted the hydrogen form of the resin and the higher the salinity of the raw water, the greater the acidity. In these tests, the salinity was high, but the resin was only partly regenerated even at the beginning of the experiment.

It is probable that the small amount of bacteria passing into the anion-exchange column multiplies there. Bacterial examination of pilot plant samples seems to confirm previous observations (3) that weakly basic anion exchangers may act as media for bacterial growth.

It may be supposed that the bacterial purity of the treated water can still be maintained if bacterial growth on the anion exchanger is checked at frequent intervals and the number of bacteria is not allowed to build up to any appreciable degree. Recently published investigations have shown that the sterilization of cation exchangers by very dilute solutions of bactericidal agents like formaldehyde yields satisfactory results (4). If suitable sterilizing agents were added to the anion exchanger regenerant in each regeneration, or after a fixed number of them, the bacterial population in the treated water might be materially reduced, thus effecting partial or complete disinfection of the raw water without introducing foreign chemicals.

It remains to be seen how microorganisms other than *Esch. coli* respond to partial demineralization, what minimum acidities and flow rates should be maintained and how periodic disinfection of anion exchangers affects the purity of the treated water.

Summary

1. Bacteriological examination of samples from a pilot plant for partial demineralization of brackish waters showed that the cation-exchange effluent was free of bacteria, while the anion-exchange effluent was heavily contaminated.

2. Laboratory experiments using sterilized apparatus showed that partial demineralization of a soft, brackish water, with about 2,000 ppm. dissolved solids, containing about 1,000 *Esch. coli* per milliliter, caused complete destruction of the bacteria at the beginning of the run, and, when the resins neared exhaustion, less than 10 and 100 bacteria per milliliter were found in the cation and anion exchanger effluents, respectively.

Acknowledgment

The authors wish to thank E. D. Bergmann, Scientific Director, Weizmann Institute, for his valuable advice, and W. Juda, of Ionics, Inc., Cambridge, Mass., and A. Amrami, of the Israel Health Ministry, for their very useful suggestions.

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A New Method for Determining Methane in Water

By J. R. Rossum, P. A. Villarruz and J. A. Wade Jr.

A contribution to the Journal by J. R. Rossum, San. Engr.; P. A. Villarruz, Asst. San. Engr.; and J. A. Wade Jr.; all of California Water Service Co., San Jose, Calif.

THE presence of methane in water may involve a considerable explosion hazard, and there are indications that it plays a role in supporting bacterial growth in mains. Although two excellent publications on the significance of methane in water have appeared (1, 2), very little has been published on methods for its determination. The gases evolved by boiling the water sample may be analyzed by the usual gasometric methods, but the water sample must be collected under pressure and the procedures require considerable time. A qualitative test is made by filling a large bottle almost full of water, sealing it, allowing it to stand for a while and attempting to note a flash when the gas in the air space is ignited. This test is best performed in a darkened room. It is not reliable, however, if the water is supersaturated with nitrogen. According to a communication from T. E. Larson, a positive flash test is a rough indication that methane is present in quantities in excess of 1 cu.ft. per 1,000 gal. (5.4 ppm.) when the air space is about 100 cc. in a gallon container.

The authors have devised a test for methane that requires only a few minutes of the analyst's time and appears to have adequate accuracy and sensitivity to meet the requirements of water works laboratories. The principle of this test depends upon the equilibrium established, according to Henry's law, between the concentration of methane in solution and the partial pressure of methane in the gas phase above the solution. The partial pressure may be determined with an instrument, popularly known as a "sniffer," which was developed primarily to test for explosion hazards due to the presence of combustible gases in air. Its operation is based upon the catalytic oxidation of the combustible gas upon a heated platinum filament. The heat of oxidation raises the temperature of the filament, which, in turn, increases the electrical resistance of the platinum. The resulting unbalance of the electrical circuit causes the deflection of an electric meter, which is calibrated to indicate the concentration of combustible gases or vapors in the gas sample.

Under the conditions of the test, Henry's law and the perfect-gas laws apply to methane with sufficient accuracy for the purpose. From these laws, it can be shown that the total weight, W (mg.), of methane in a sample may be expressed by:

$$W = P\left(0.257\,\frac{V_g}{T} + 890\,\frac{V_s}{H}\right) \quad (1)$$

in which P is the partial pressure (mm. Hg) of methane; V_g and V_s are the volumes (cc.) of the gas and liquid phases, respectively; T is the temperature (°K.); and H is the Henry's law constant (mm. Hg per mole fraction).

As gas samples much smaller than a liter cannot be conveniently handled, the water samples are collected in a gallon jug not more than three-fourths

filled with the sample. The sample bottle has a two-hole rubber stopper fitted with two glass tubes, the inlet tube extending to within about 1 cm. of the bottom of the bottle, and the outlet tube being adjusted so that the bottom is about midway between the water surface and the top of the bottle.

Water is introduced through a rubber tube connecting the sampling tap to the inlet tube of the gallon jug. When it is filled to the desired capacity, the inlet and outlet tubes are immediately connected with a short length of rubber tubing. When received in the laboratory, the sample is shaken vigorously for 60 seconds and allowed to stand for two hours. The gas mixture is then tested by drawing the gas above the sample through the outlet tube into the "sniffer."

The rate at which equilibrium is established during shaking has been determined over a wide range of methane concentrations. Based on these data, a shaking period of 60 seconds was arbitrarily chosen. The 60-second shaking period is essential even if the samples have been transported some distance or allowed to stand for a considerable length of time. It has been found that equilibrium between the methane in the solution and in the gas phase is not established for several days when the sample is permitted to stand at room temperature.

The two-hour standing period was also arrived at experimentally. Identical samples were taken and, after shaking, were allowed to stand for various periods. After 15, 30 and 60 minutes' standing, the results for a series of samples differed materially, and, in general, the apparent concentration increased with the standing period up to two hours. After two hours the results were consistent, although the reason for this phenomenon is not clear.

The "sniffer" selected for this investigation was a Model 2 Explosimeter, made by the Mine Safety Appliance Co. According to the manufacturer, this instrument will measure the concentration of combustible gases with a maximum error of about 10 per cent, although the two actually used by the authors have been much more accurate. The meter is calibrated to read directly in percentage of explosive gas mixture, and, again according to the manufacturer, a correction factor of 0.77 should be applied for methane. Since the lower explosive limit for methane in air is taken as 5 per cent by volume, a meter reading of 100 is equivalent to 0.77×5, or 3.85 per cent methane in air. From this figure, it is possible to derive an equation relating the partial pressure of methane in the gas sample to the instrument reading. This equation can be combined with Eq. 1 to give an equation for the methane concentration in the water sample. The latter equation (Eq. 2) is, of course, valid only for the instrument model mentioned above. With the methane concentration, C, in ppm.:

$$C = 0.385 S \bar{P} \left(\frac{0.257 V_g}{T V_s} + \frac{890}{H} \right) \quad . . (2)$$

in which S is the instrument meter reading; $\bar{P}$ is the barometric pressure, in mm. Hg; and V_g, V_s, T and H are expressed in the units specified for Eq. 1.

The value of H at 20°C. is 28.53×10^6 mm. Hg per mole fraction, and normal variations in atmospheric pressure will not affect the results within the accuracy claimed for the determination. Equation 2 may be greatly simplified by assuming a constant temperature of 20°C. and a constant barometric pressure of 760 mm. The ratio of volume

of gas to volume of sample should be accurately determined.

When the methane concentration is low, the sample bottle should be filled about three-fourths full, while, if the water is supersaturated with methane, the bottle should be about one-fourth filled with sample.

Although the Model 2 Explosimeter is suitable for use as delivered, it was found that a significant increase in sensitivity and a slight increase in accuracy could be obtained by replacing the suction bulb with a laboratory filter pump throttled so as to draw gas through the instrument at a rate of about 600 cc. per minute. A two-way stopcock was inserted between the sample and the instrument, so that the meter could be set at zero while drawing through atmospheric air, and the sample reading obtained by turning the stopcock.

The method is not specific for methane, since any other combustible gas will give a reading on the Explosimeter. Generally, methane is the predominant combustible gas in water, although many waters contain appreciable concentrations of hydrogen sulfide, and some contain ethane and higher hydrocarbons.

The possibility that methane may be consumed by biological activity during shipment of samples has been considered. Hutton and ZoBell (3) have shown that certain bacteria will consume methane at appreciable rates under somewhat similar conditions. According to these investigators, the optimum conditions for bacterial utilization of methane are 10–40 per cent oxygen, 20–70 per cent methane, 5–10 per cent carbon dioxide in the gas phase, and a pH of 6.5 in the solution phase. Since these conditions would not normally be encountered in water testing, it is concluded that the loss of methane through bacterial action would not be significant unless the period between sampling and testing was greatly prolonged.

Table 1 compares the method described in this paper with a standard gasometric method for determining methane in water. The sensitivity of the proposed method is such that 0.2 ppm. of methane can easily be detected. More accurate instruments are available, and possibly more accurate results could be obtained by their use, but, for practical purposes, the extra expense does not seem justified. Sensitivity could probably be increased by using larger sample containers so that lower ratios of gas to sample volume could be employed. The proposed method has been used in the authors' laboratory for several months to evaluate the explosion hazards due to methane in water.

TABLE 1

Methane Determination

Methane—*ppm.*	
Std. Orsat Method	Proposed Method
21.7	22.2
20.3	21.0 20.5
14.0	14.3
9.3	9.4
6.0	6.2
2.9	3.0

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The Present Status of Public Water Systems in Florida

By John S. Telfair Jr.

A paper presented on Nov. 15, 1949, at the Florida Section Meeting, Orlando, Fla., by John S. Telfair Jr., San. Engr., State Board of Health, Jacksonville, Fla.

THE task of defining the status of the public water supplies of Florida is not unlike the problem which the blind men faced in describing the elephant. Like them, the author's view of the situation will be colored by the parts he has touched personally. Probably not very far wrong, but certainly not entirely true, the observations and opinions expressed are the author's own and do not necessarily represent the position of the state health authority.

The statistics which follow are fairly accurate, being based on a complete inventory by the board of health staff in 1948 and brought almost completely up to date. Since Florida's population grows like a bloom of algae in a reservoir, it is conceded that the population figures are all low, but the percentages are reasonably consistent.

The water works industry serves daily about 80 per cent of the total population of Florida. Taking a low capital replacement cost figure of $60 per capita, this represents an investment of over $108,000,000. Water production qualifies as one of the state's major industries in terms of dollar value alone. Aside from an indispensable position with regard to public health and the furnishing of industrial lifeblood, it is also the principal source of the revenue needed to support other municipal functions in many, or even most, municipalities. Many systems have been bled white since the adoption of the Homestead Tax Exemption Law.

The diversion of water works funds, together with the phenomenal rate of population growth, has caused many systems to fall behind in their improvement programs. Fifty-seven Florida communities, with a combined population of 39,000, need entirely new water systems. The estimated cost (in 1946 construction dollars) is $2,894,000, or $74 per capita. A total of 366 Florida water systems, serving a combined population of 1,201,000, need $35,110,000 worth of major improvements ($29 per capita). Total requirements for new capital outlays, then, are set at $38,004,000. Any decline in costs since 1946, as well as the $9,940,000 worth of construction accomplished or under way, will have been offset by continuing population gains.

It is well to mention that Florida statutes define a public water supply as any system serving more than 25 inhabitants, regardless of ownership. The figures presented below, however, are based upon an accounting of only those systems which serve not less than 100 persons (roughly 30 service taps). Military establishments are also excluded. Florida has approximately 382 such public systems, 92 of them serving subdivisions, mostly located in Dade

and Duval Counties. Consequently, 290 public water supplies in the state are identified with some city or town and are more or less municipal in character, although not necessarily in ownership. These 382 systems serve water to an estimated 1,815,000 persons, about 80 per cent of the 1945 population.

Supply Sources and Treatment

By far the greater number of systems employ deep well sources.

Deep ground water. A total of 340 water plants, serving 1,334,000 people, derive their supplies from deep limestone wells. Miami and nearby systems, using relatively shallow limestone formations, are included, perhaps not too logically, in this category.

Shallow ground water. From wells drilled into unconsolidated formations, usually near the surface, 19 plants derive water for 108,000 people. This category includes Pensacola and Milton, both of which have rather deep wells in sand-gravel aquifers.

Surface water. From Florida's rivers, lakes, ponds, creeks and springs, 23 plants supply 378,000 persons.

The state health officer not long ago remarked: "In our congested, modern society, safe water is a manufactured product." Given acceptable sources, the plants for the manufacture of safe water are perhaps an even more significant item in this accounting.

Complete treatment. Some 1,000,000 persons (about 56 per cent of the *connected* population) drink water which is completely treated. There are 47 treatment plants of various designs, using various processes for the reduction of hardness, turbidity, color, taste, odor and bacteria loading. Each plant in this category employs softening or coagulation, and filtration and chlorination. (Although softening plants are included in this category, filtration plants for iron removal are not. At Vero Beach, disinfection is accomplished by lime softening at excessively high pH ranges, a method which has been rather effective but adversely affects the distribution system.)

Disinfection only. Water from various sources, with chlorine disinfection the only treatment, is served to 524,000 people (29 per cent of the connected population) by 84 systems. Of these, 74 use deep well sources; 8 use shallow wells; 1, a spring; and 1, a lake. One plant, using chlorine solely for iron removal, is listed in this category.)

Untreated. A total of 253 systems serve 289,000 people (15 per cent of the connected population) with raw water. Several of these plants aerate the water, but no other treatment is included in the category.

Perhaps a clearer picture than that provided by statistics can be obtained by considering more closely three actual plants—the largest, the smallest and one of average size.

Greater Miami System

In terms of connected population, production or capital investment, or on almost any other basis, the Greater Miami water system stands first in the state. Unique in so many ways, it yet typifies all Florida plants of comparable size in certain respects. Basically a lime softening plant, it handles a raw water posing a color removal problem. It is almost entirely correct to say that the plant ("plants" might now be preferable) is under construction and has been almost constantly for over 25 years. Ten years ago the maximum rated capacity was 40 mgd. and the av-

erage production was 19 mgd. In 1948 the rated capacity was up to 60 mgd. and the average production approached 40 mgd. It has been anticipated that peak days in early 1950 will greatly exceed the plant's capacity, and unsoftened water, disinfected by free residual chlorination, will be pumped from the new southwest well field to make up the deficit.

Smallest Florida Plant

Other than to say that it serves a small North Florida agricultural community, the state's smallest municipal water system will be unidentified. The system, which serves about 100 townspeople and 300 students of a consolidated school, consists of one deep well, one pump, one chlorinating machine, one elevated tank and approximately 2 miles of mains varying from 6 to ¾ in. in diameter. The superintendent, who is also the bill collector, repair crew and mechanic, plants tobacco on the side and operates the town grist mill.

The original water system in this town was established in 1913, after a disastrous typhoid epidemic stemming from shallow drive-point wells, surface privies and poor drainage. The present well was drilled at that time, and an old, steam-driven jack was the original pump. When it gave out about 1925, a gasoline-driven deep well piston pump was installed. The town is in sinkhole country, and the well site can be flooded at times. The old casing gradually corroded down almost to ground level and surface water must have seeped in. During 1943 (when the state health department's bureau of engineering consisted of two men) the water showed pollution, and a state-owned chlorinating machine was installed by a U.S. Public Health Service engineer. Under duress, the town purchased its own machine.

The town, perennially bankrupt, had given a franchise to the operator, stipulating that he pay for water department operation and keep whatever money he could wring out of the customers. The author does not know who paid for the chlorinating machine, but neither party was willing to pay for chlorine—with the obvious consequences. Finally the state board of health gave a permanent warning to the citizens that water should be boiled for safety. Generally, however, it was possible for the board to keep a fairly close watch and chlorination was kept up on a month-to-month basis.

The state continued urging major improvements, and finally the town council reassumed financial responsibility. Board of health engineers shared in leading the way to the construction of a new concrete block pumphouse, a 3-ft. extension of the well casing and the installation of a new electric deep well turbine and permanent chlorinating apparatus. A board of health engineer lived on the job and eventually used up about 75 lb. of 70 per cent hypochlorite powder in disinfecting the well and distribution system. The author is happy to report that the plant site is cleaned up, chlorine is purchased in 100-lb. drums, raw-water samples are usually satisfactory and distribution samples invariably meet drinking water standards. The staff of the bureau of engineering finds as much satisfaction in the present condition of that system as it does in considering Miami's vast enterprises at Hialeah and Coral Gables.

Median System

The systems previously described are the extremes—truly a part of the pic-

ture, but only a part. It is also necessary to examine the municipal water system which stands precisely in the middle—the median system. Since population figures are more accurate, on the whole, than estimates of plant production, connected populations have been used as the basis of comparison. On that basis, Florida's median system is in a town of about 1,200 inhabitants, of whom 1,100 are connected for water service. The city is not very far south of Jacksonville.

The water plant consists of one deep well, two horizontal centrifugal well pumps, a splash aerator, a coarse upflow filter, a gas chlorinating machine and a 175,000-gal. covered reservoir. There are two service pumps of 200- and 600-gpm. capacity, respectively. An elevated steel tank with a 75,000-gal. capacity floats on the system. The raw water used by this system is highly mineralized.

The original plant, built in 1927, consisted of the well, reservoir, tank and pumps. There was an island aerator of the coke bed type. The present aerator-filter unit is an appendage tacked on by the WPA in 1935. The chlorinating apparatus was added in 1942, and, to the author's knowledge, this system is the only one in the state where oxidation of iron by chlorine is practiced as such. In 1948 a gasoline engine was connected to one of the two well pumps in order to provide direct pumping of untreated water during power outages. The smallest service pump uses three-phase, 220-v. power. Others are wound for a primary-circuit voltage of 2,200.

Water can be pumped to service at the rate of 700 gpm. (1 mgd.), but the effective plant capacity is limited by the yield of the only well to 145 gpm. (0.2 mgd.). The present output is about 75,000 gpd.

The distribution system consists of 9 miles of universal cast-iron pipe, ranging from 2 to 10 in. in diameter. There are 95 valves, and the entire system is well looped. The three dead-ends have to be flushed about every ten days, and yield a beautiful slug of red water.

The domestic water rates are $3.00 for the first 4,000 gal. and 20¢ for each additional 1,000. Commercial rates are a straight 25¢ per 1,000 gal.

The financial position of the system is indicated by the bonded-debt figures. Of a $94,000 original issue in 1927, $72,000 was outstanding in 1949. A total of $12,000 was retired between 1927 and 1940, and the balance was refunded in the latter year at 3.5 per cent. The interest rate rose to 4 per cent in 1945. Bonds are not callable—an item of academic interest, apparently.

The plant valuation was originally $100,000, according to town officials. An estimate of present value (replacement cost less depreciation) would be nearer $40,000. The distribution system value would amount to approximately $78,000 on the basis of 50-year life for cast iron. Thus, of an approximate original value of $275,000 at present-day costs, depreciated, there is a residual value of perhaps $120,000, with a bonded debt of $72,000, or 60 per cent. On a per capita basis, the original valuation would have been $228. At actual costs then prevailing, it was about $135—still high. The residual value in terms of present costs is about $100 per capita, and the remaining bonded debt $60 per capita.

Even though depreciation seems to run neck and neck with debt retirement, and the water rates are certainly

not low, there seems to be little left over for operation and maintenance. Operating costs in 1948 totaled $6,500, of which $2,100 was the superintendent's salary.

There has been only one superintendent, who is also the entire water department staff, except for a bill collector (the city clerk). The superintendent, who was a foreman during plant construction, is now 62 years old. His present salary of $175 a month was instituted in 1948, after remaining static at the level of $125 for 21 years. During the depression of the 1930's, the salary became so static that it ceased. The superintendent was forced to borrow food money from the bank but fortunately had collateral. He is able to live today partly by virtue of his skill at making casting nets, which he does during wet-weather sieges of arthritis.

This man is a conscientious, hard-working public servant. With no formal schooling beyond the seventh grade, he is a mechanic, electrician and pipe fitter. His normal working day is only eight or ten hours, but he is on call 24 hours, seven days a week—some attendance to the job is required 365 days a year. During the past 22 years he has had no vacation and has attended no short courses.

It is readily conceded that this median plant does not fully describe the situation, but it does illuminate a few significant points:

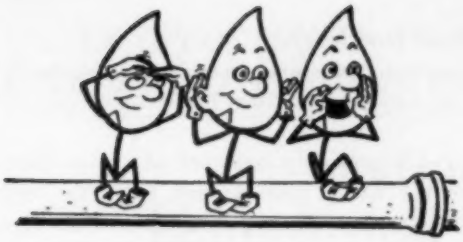
1. The problems of the water works industry in Florida are those of the small system in the small city or town.
2. The position of many, even most, of the operating personnel is not a happy one, and the rewards are not enough to attract additional good men.
3. It follows, more or less naturally, that operation and maintenance are often inadequate and unsatisfactory.
4. The subject of public relations is usually unheard of. Water to most citizens means merely turning on a tap.
5. To many small city councils, the water works operator is a laborer on a par with the garbage collector.

Conclusion

To serve the water works industry in Florida, interest should be directed largely to the problems of the small system in the small city or town. There is much to be done in advancing the operation of water works, especially in the smaller communities. A great deal is being accomplished through short courses, but even more could be achieved by working out a classification and salary schedule to recommend to city governments.

In the field of public relations, it is necessary to foster an appreciation by the lay public of the water works industry and its personnel.

As individuals and through their associations, water works men can discourage the building of systems too expensive to pay for or too complex to operate properly on a limited budget.



Percolation and Runoff

If you want water these days, you apparently pays your money and takes your choice between mysticism and science—dowsing, that is, and rainmaking. Of course, common sense does still enter into the picture once in a while—as in the case of the Pirnie-Friel report on the tristate Delaware River project—but, since the slide rule isn't nearly as romantic as the peach twig or the dry-ice bomb, that's something you can't "see by the papers."

What's so attractive about these two opposites in technique is that they both still have many more skeptics than proponents or opponents. Dowsing has been in that equivocal position for at least 22 centuries and promises to remain there for 22 more. And though by its very scientific nature, the rainmaking question is bound to be answered in a matter of mere years, for the moment it is stealing the diviner thunder.

Right now rainmaking is making its biggest splash by virtue of New York City's decision to give it a fling. Thus, in the metropolitan area, anything that bears upon the subject of cloud seeding is first-rate news. In the past few days, for instance, we've been undergoing a siege of information giving blow-by-blow accounts of the City's cloud-by-cloud consideration of the possibilities and reporting the status of cloud-busting in such other areas as California (where the California Electric Power Co. claimed a 12 per cent bonus of snowfall after a secret two-year experiment), New Mexico (where a 320-bil.gal. cloudburst was produced at a cost of $20 in silver iodide) and Arizona (where the Salt River Valley Water Users Assn. of Phoenix has installed land-based silver iodide vapor units following a demonstration that four times as much rain fell in a test area as outside it). Meanwhile, of course, all is not "pro" in the big city. Not only have outlying farmers warned authorities not to mess up their crops with ill-winded storms and Godfearing citizens cautioned them not to tamper with Nature, but the proprietors of a country club in the vicinity have already filed suit to restrain the city from thus ruining their business. As we have noted many times during the meteoric rise of the rainmakers, there's going to have to be a law; and locally, at least, such a law is already

(Continued on page 2)

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on the docket of the State Legislature. Of course, even if someone figures out a way to make the rain drop only into his own bucket, someone else is going to want that rain.

With dowsing, the situation is different only inasmuch as a good dowse does not directly affect anyone but the person dowsed for. Yet even with this publicity handicap, dowsers have been getting more than their share of headlines ever since the printing press was invented. Thus, despite the fact that Wun Kwik Dip did it in China in the second century B.C., that German miners accomplished it with the *schlagruthe* before 1400 A.D., that it was done with the sidereal pendulum as early as 1700 A.D.—when William M. Chaney of Hagerstown, Md., recently pointed out a ground water supply with a "gadget" of his own making, it again rated a two-column story with pictures in the local press. The fascinating feature of all this business, of course, is that even its practitioners don't know what it's all about. Nervous stimuli, electromagnetic radioactive rays, osmosis, water-induced epilepsy, penetrating vision and hearing, innate geological competence have all been advanced as explanations, less often by the dowsers themselves than by those scientifically convinced. With most people, however, it isn't the explanation of the fact as much as the fact itself that's unbelievable. And such feats as Chaney's 600 successful dowses, which provided accurate data on depth, area and quantity of subterranean supplies, are usually explained away as good guesswork, good luck and the convenient memory of local supporters. We, ourself, have written the subject off innumerable times, but it always crops up again to plague us, if only in the form of curiosity concerning the disposition of dowsers who fail.

So now again, primarily because we have yet consciously to drink a drop of either "dowsed" or "induced" water, we're swearing off the subject —at least until some really conclusive evidence turns up. And nowadays, when they're able to establish scientifically that the Red Sea did actually separate, that ain't impossible. Meanwhile we'll promise to string along with the less sensational aspects of mere engineering, which, when you come right down to it, is a reasonably satisfactory expedient for obtaining water supply, at least until the real thing comes along.

At the concrete pipe industry convention held in San Francisco last February, the newly formed American Concrete Pressure Pipe Assn. affiliated with the 43-year-old American Concrete Pipe Assn. to form the coordinating master organization known as Concrete Pipe Associations Inc. Howard F. Peckworth acts as managing director of all three organizations, with headquarters in Suite 1364, Builders Bldg., 228 N. LaSalle St., Chicago. As a result of the affiliation of the two groups, one industry group represents manufacturers of concrete pipe for water supply and other pressure uses and for irrigation, drainage, sewers and culverts.

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(Continued from page 2)

United effort of the entire Association is needed in the preparation of the Tenth Edition of *Standard Methods*. All members are urged to correspond with R. L. Derby, Chairman, Committee W-9 (Chemical Methods), regarding current deficiencies and to recommend changes or additions in the standard procedures. All correspondence will be given careful consideration and will be referred to the proper subcommittees for further study and action.

Volunteers who are interested in carrying out studies of certain tests mentioned in *Standard Methods* are also urged to communicate with Chairman Derby (Principal Sanitary Engineer, Dept. of Water & Power, 207 S. Broadway, Los Angeles 12, Calif.). At present interest appears to be concentrated too greatly on certain procedures, leaving subcommittee vacancies in the following fields:

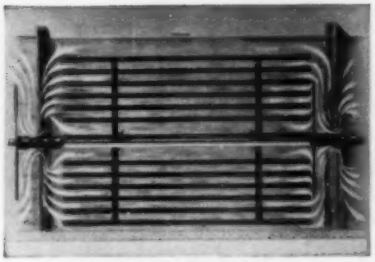
color and turbidity
pH (electrometric)
buffers and indicators
sodium and potassium
silicon, iron and aluminum
polarographic methods
chlorides, bromides and iodides
phenols and cyanides
phosphates
sulfates
dissolved oxygen
tannin
magnesium
effect of free chlorine on other tests
microscopic determinations for algae
arsenic, boron and selenium

The work of studying these procedures is essential to the preparation of the next edition of *Standard Methods for the Examination of Water and Sewage*, and those who have a professional interest in broadening our knowledge of, and improving the techniques for, these tests are urged to respond.

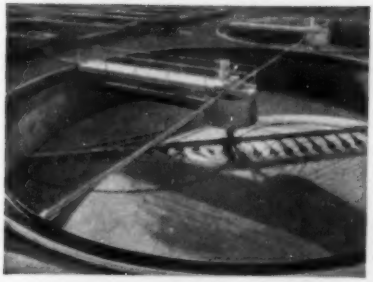
Better than a better mousetrap and certainly a lot more timely is "Beetsol," a new hand cleanser that requires no water. Now if this new product—which is supposed to "remove grease and grime in half the time" required by a soap and water scrub, and to banish paint, tar, ink, oil, asphalt, even glue, while soothing and refreshing the skin and not removing nail polish—can be properly sold in New York City, a big chunk of Water Commissioner Carney's problem ought to be solved. Brought to our attention by its distributor, Burrell Corp. of Pittsburgh, "Beetsol" is apparently a vegetable derivative, manufactured by the Sugar Beet Products Co. of Saginaw, Mich. Now if we can only find a way to make onions wash more than just two little streaks down our faces, we ought to be all set to go clean through another drought right in our own gardens.

(Continued on page 6)

It's a Matter of Record...



Rex Floctrol



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and in plant after plant, the records show that Rex Water Treatment Equipment provides unequaled efficiency . . . sets the standards for economical, long-life operation.

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CHAIN BELT COMPANY REX SANITATION EQUIPMENT

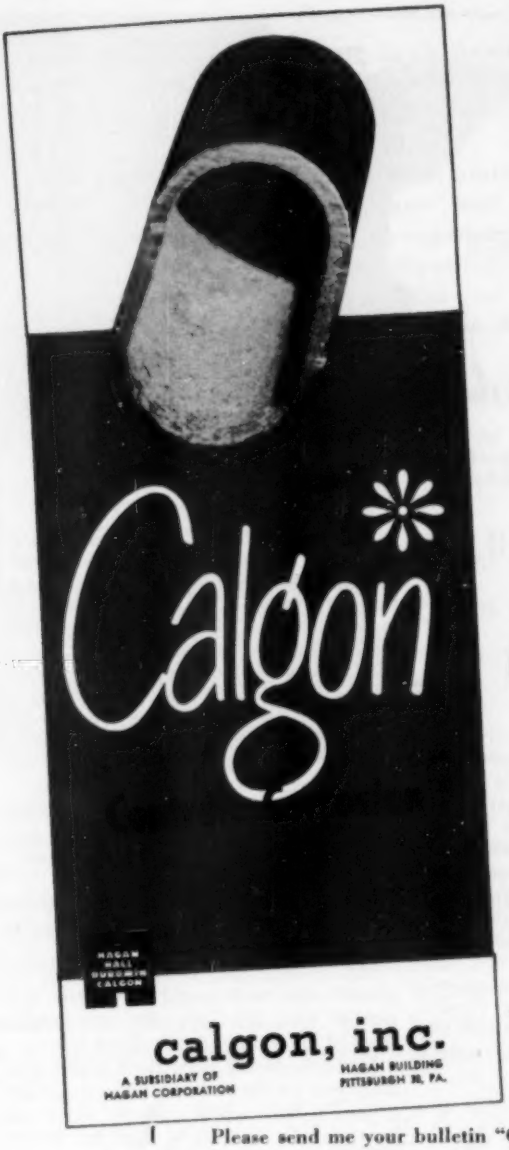
(Continued from page 4)

New York Story

Courtesy H_2O *(American Water Works Co. & Northeastern Water Co.)*

"Wonderful day, isn't it?"

(Continued on page 8)



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J-4

(*Continued from page 6*)

The immediate enthusiasm which greeted A.W.W.A.'s call for entries in an amateur photography contest to be exhibited at the Philadelphia Conference next month convinces us that an awful lot of water workers received cameras for Christmas. After all, it was only last year that we were vainly SOS'ing for cover picture material. Could be, of course, that all the present contenders were then "contenters." At any rate, we're more than satisfied with present coverage—as apparently you are—and we're looking forward to viewing what might have been.

In the event that you, too, indulge in focus pocus and missed the previous invitation, the details of the contest are noted below:

General Rules for A.W.W.A. Photographic Exhibit Philadelphia Conference, May 21–26, 1950

The photographic exhibit is for entries submitted only by members of the Association, and shall be of the following types of photography:

Black and white photographs
Kodachrome, Ektachrome or Ansco color prints
Black and white transparency projection slides
Kodachrome or Ansco color transparency projection slides
Microphotographs

Developing, printing, enlarging or processing may be done by a photofinisher or laboratory, but exposure of the original negative must be the personal work of the entrant. Do not mount photographs. No art work or retouching should be done to prints or the negatives from which they are made. No composite pictures, multiple printing or montages are acceptable as entries. Cropping is permissible.

Suitable awards will be made for prize-winning entries in the following classifications, all of which must be related to or have some connection with water works or the operations thereof:

Construction: Pictures of work in progress or in completed form.

Operations: Pictures of plants, equipment and people engaged in usual or unusual work and functions.

General Interest: Subjects may be buildings, plants or people, conditions of emergency or disaster, civic activities, etc.—all of which must relate to or affect water works operations.

Microphotographs: Pictures usually obtained from laboratory or sanitary research work. No trick photographs of the "What is it?" type are eligible.

Entrants shall specify the classification in which the picture is to be entered. Unless so indicated, the judges will place the entry in the class in which they believe it belongs. An entry may be made in each classification, but it shall consist only of one photograph or slide, except in the Construction classification where as many as five related entries may be made if continuity is thereby obtained in showing the progress of work or the results thereof.

Black and white or color photographs should be not smaller than 4×5 in., nor larger than 10 in. in the longest dimension, and should be unmounted.

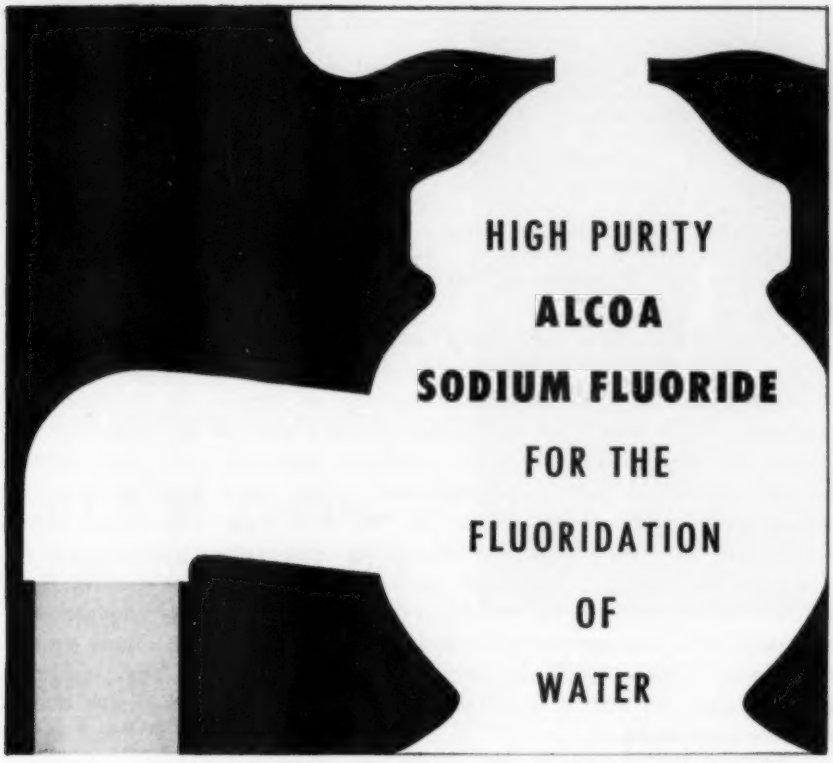
Transparency projection slides may be in the 35 mm., 2×2 in. or $2\frac{1}{4} \times 2\frac{1}{4}$ in. sizes.

Microphotographs should be printed on glossy paper and should be of size not smaller than 4×5 in. and not larger than 10 in. in the longest dimension.

Entrants should print their names and addresses on the reverse side of photographs. Be careful not to press so heavily with the pen or marking device that the surface of the photograph becomes marred. If possible, transparency projection slides should bear the name and address of entrants. If the slide margin is inadequate, a card giving such information should accompany the slide.

The title caption or explanation of each picture or slide may be printed on

(*Continued on page 10*)



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If your community is fluoridating its water supply—or is considering doing so—let us discuss with you the properties of ALCOA Sodium Fluoride that make it particularly suitable for your use. Write to ALUMINUM COMPANY OF AMERICA, CHEMICALS DIVISION, 624 Gulf Bldg., Pittsburgh 19, Pennsylvania.

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(*Continued from page 8*)

reverse of picture or margin of slide, if space permits; otherwise it may be typed upon a separate card. Briefness in titling is advised.

Do not mount photographs. They will be afforded a suitable display in a prominent location.

Arrangements will be made to provide for screen projection of slide entries.

All entries will be judged on their appeal, or the general interest they arouse. Photographic technique and excellence, while important, will not be the deciding factor.

Entries should be carefully packed and forwarded, *after May 1, 1950,* to:

R. L. Tyler
American Water Works Co., Inc.
121 S. Broad St.
Philadelphia, Pa.

The "Meter New York City" campaign, which has been budding furiously as a result of the current water shortage, may yet be nipped by the opposition of the city's landlords. Actually, of course, the problem of equitable distribution of water charges within a multiple unit dwelling is not an easy one, but the landlord's conscience cannot be quite clean when he suggests that "tenants would deliberately waste water to get even with the landlord." As a matter of fact the New York water department now has information from most of the metered big cities in the country to prove that central metering of apartment houses will do wonders in making the landlord repair plumbing leaks and that the practice has been of unquestionable value both in conserving water and in establishing rates on a more equitable basis. Unless landlords, themselves, have given New York tenants greater cause, we sort of doubt that they'll be any more vindictive than those of other cities.

Well aware, anyway, of the patent unwisdom of outright opposition to any means of conserving water in these desiccated days, the landlords chose first the old "kiss of death" technique—advocating metering not only of apartment houses, but of individual apartments and, presumably (in view of their existing plumbing systems), of each pipe entering each apartment. And to ward off any accusations of impracticality, they summoned aid not only of their superlogicians of equitability, but of such amateur supporters as the *Times* letter writer, whose solicitousness took this unusual tack:

> The city should take the initiative in encouraging inventors to devise small attractive-looking meters which could be affixed behind faucets or on water lines anywhere. Almost certainly, with sufficient financial incentive, such inventions would be forthcoming. The meters might well be chromium-plated so that they would not constitute eyesores. Their manufacture and installation should be contracted for on a large scale. This would keep the price low and eliminate any undue burdens on the tenants.

Failing even so to arrest the endeavor, the Real Estate Board of New York has turned now to another embrace, endorsing the proposed metering

(*Continued on page 12*)

10,000 FEET MORE

of the modern main
that shortens the job
and lengthens the service

IT'S K&M "Century" ASBESTOS-CEMENT PIPE

The light weight of this strong K&M Asbestos-Cement Pipe cuts shipping and haulage costs sharply; permits of more economical laying equipment; saves many dollars' worth of time. Even when a radius requires as much as 5° deflection per pipe length, it is easily swung with the "Century" Simplex Flexible Couplings regularly used. This feature, in conjunction with lightness, speeds up any alignment needed before backfill.

Yet all of that merely begins the economies now winning increasing favor for K&M Pipe. This advanced pipe defies electrolysis and is highly resistant to soil corrosion. It doesn't know tuberculation effects; therefore, inside diameter, flow capacity and calculated pumping costs hold constant.

Traffic stresses, earth settlement and chemical attack are all minimized by K&M Asbestos-Cement Pipe—the main that the years don't weaken! As a final economy this pipe is recoverable for re-laying in its original pressure class. You can see why the savings made and the service assured always do credit to those responsible for K&M "Century" Pipe installations. Write us for full data.

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Nature made Asbestos . . .
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K&M last in asbestos ®

(*Continued from page 10*)

program almost unqualifiedly—that is, subject to five "conditions," not the least of which is that the city must "favor applications by owners to whatever authority was then administering residential rent controls for adjustments of rents to permit passing along to the tenants any increase in water charges." Of course, we don't believe there would be any increases in water charges unless some real effort were exerted to incur them. Since even that is not beyond the realm of possibility in this friendly city, however, we hasten to defret Commissioner Carney. Having experienced New York rents at their present level, we are convinced that any further increases will automatically result in some of those vacancies which landlords apparently want and which current rent ceilings have more or less thwarted. And as New York City's tenant population migrated to the surrounding countryside, at least its water consumption would be reduced in proportion.

The 18th Annual Short Course and Conference sponsored by the Florida Committee on Water Supply and Sewerage Education is to be held at Gainesville June 5–10. As in the past, a continuous training program for water, sewage and swimming pool personnel will be provided.

A Meter Repair and Allied Activity School sponsored by the North Carolina Section is to be held in Winston-Salem on April 21 and 22. Registration will be in the lobby of the City Hall, and the only fee will be the cost of a Dutch Supper. J. L. Greenlee of the Charlotte Water Dept. is acting as chairman of the arrangements committee.

Edward Hyatt, chief of California's Div. of Water Resources and state engineer, has retired after more than 35 years of service. He began his career with the state in 1914 as an engineer with the Highway Commission and two years later was transferred to the newly organized Water Commission, now known as the Div. of Water Resources.

(*Continued on page 16*)

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BOYCE COMPANY

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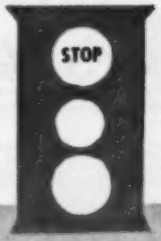

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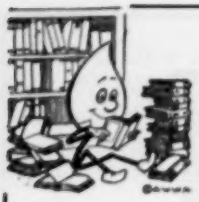


The Reading Meter

Hydroelectric Handbook. *William P. Creager & Joel D. Justin, ed. John Wiley & Sons, New York (2d ed., 1950) $12.50*

By one of those quirks of fate this volume appeared just a few days after the death on February 21 of Joel D. Justin, the junior editor. The 1,150-page, 5-lb. tome is intended as a compendium of hydroelectric practice for both student and practicing engineer. Certain chapters—such as those on rainfall, runoff, river gaging, stream and flood flows, hydraulics, storage, dams, intakes, pipe and water hammer—are of almost equal interest to the water works field.

Engineering Papers of Hydraulic Institute, Vol. II. *Hydraulic Institute, 90 West St., New York 6 (1950) $2*

This 62-page booklet contains four award-winning engineering papers by employees of the pump manufacturers for which the institute serves as a trade organization. The papers are "Cavitation in Centrifugal Pumps" by A. J. Stepanoff, "The Centrifugal Pump in the Process Industries" by A. T. Nielsen, "The Operation of Centrifugal Boiler Feed Pumps" by Hans Gartmann, and "Submergence for Centrifugal Condensate Pumps" by Hollis T. Waldo.

Bibliography of Polarographic Literature. *Bibliog. E-90(1). Leeds & Northrup Co., 4907 Stenton Ave., Philadelphia, Pa. (1950) free*

A bibliography of 2,208 references, from the earliest preliminary investigations in 1903 up to mid-1949, is offered to research workers interested in polarographic analysis. The listing is chronological, with subject and author indexes included, and forms a booklet of more than 100 pages.

A.S.T.M. Standards on Industrial Water. *American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. (1950) $1.75*

A 142-page compilation, paper bound, of various A.S.T.M. standards—26 in all—for sampling, analysis and testing of industrial waters, particularly those intended for steam generation, process or cooling purposes. Corrosivity tests and a bibliography of A.S.T.M. symposiums and technical papers are also included.

Builders Pneumatic Filter Gauges are becoming increasingly popular with water works men. These features tell why!

SIMPLE CLEAN-CUT INSTALLATION. Builders Pneumatic Gauges make possible the complete elimination of cables, wires, cords, and pulleys from the pipe gallery. Riser and bubble-pipes are unnecessary.

EXTREME FLEXIBILITY. Locate the transmitters and receivers wherever most convenient and connect with ¼" copper tubing.

SENSITIVITY COMBINED WITH STURDINESS. Unusual accuracy and sensitivity in equipment having the sturdy, long-life construction needed in water works service.

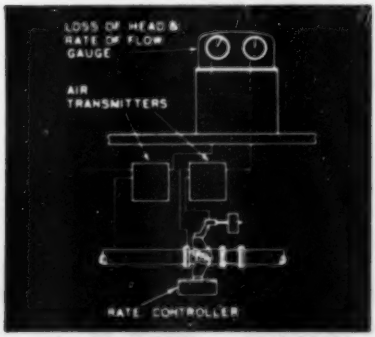
EASY-TO-READ DIALS. Uniformly-spaced graduations throughout entire measuring range.

AUTOMATIC PROPORTIONAL CHEMICAL FEED. Both dry and solution-type chemical feeders are readily adapted for proportional control from rate of flow using Builders Pneumatic Flow Meters.

SUMMATE FILTER OUTPUT. Adds flow from any number of filters or pumps and shows total flow on panel or wall mounted gauges.

TRIED AND PROVEN. Builders Pneumatic Gauges and Meters are used in the nation's most modern plants, including Chicago's South District Filtration Plant and the La Verne Softening Plant of the Metropolitan Water District of Southern California.

For complete information and descriptive Bulletins, address Builders-Providence, Inc. (Division of Builders Iron Foundry), 365 Harris Ave., Providence, R. I.



Pneumatic Filter Gauge installation for metering loss of head and rate of flow. The Pneumatic system is also ideal for checking liquid level and sand expansion, and for summation of total plant operation.

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The Venturi Meter • Propelofio and Orifice Meters • Kennison Nozzles • Venturi Filter Controllers and Gauges • Conveyoflo Meters • Type M and Flo-Watch Instruments • Wheeler Filter Bottoms • Master Controllers • Chlorinizers — Chlorine Gas Feeders • Filter Operating Tables • Manometers • Chronoflo Telemeters

BUILDERS PROVIDENCE
Instruments

(*Continued from page 12*)

Joseph W. Ellms, retired commissioner of sewage disposal for Cleveland, Ohio, died of a heart ailment on January 8. He was 82 years old. Besides his work in sewage disposal, he was known widely as an authority on water purification. He had been superintendent of the Cincinnati, Ohio, filtration plant for ten years before coming to Cleveland in 1918, and he served as commissioner from 1937 until his retirement last October.

E. Harold Johnson, representative for A. P. Smith Mfg. Co. and Worthington-Gamon Meter Co. in Florida, died suddenly on January 24, at the age of 62. Before joining the Smith organization in 1940 he had been associated with Stone and Webster Engineering Corp., Lockwood Green and Co., and the South Florida Foundry and Machine Works.

A. G. Levy, chief civil engineer for the Cleveland, Ohio, utilities department, died on February 21, at the age of 65. He had been a member of A.W.W.A. for 40 years. A native of Galveston, he had served as a captain in the Corps of Engineers during World War I and came to Cleveland in 1919.

Raymond Seydel, junior chemist and bacteriologist for the Minneapolis Water Works Dept., Columbia Heights Filtration Plant, died suddenly on December 24, 1949. He was a graduate of the University of South Dakota, from which he received an M.A. degree in chemistry in 1933, and served as a major during the war.

Builders-Providence, Inc., has moved to new and larger quarters at 345 Harris Ave., Providence, after over a century at the 9 Codding St. location (130 years, to be exact). More ample facilities will also be provided at the new address for the associated companies, Proportioneers, Inc., and Omega Machine Co.

(*Continued on page 20*)

BOND-O
Homogenized
self caulking
COMPOUND
There has never been a single reported case of a failure of a BOND-O joint.
For what other jointing compound can such claims be made?
NORTHROP & COMPANY
SPRING VALLEY, NEW YORK

FOR MORE THAN 80 YEARS

HAYS

Prices Consistent With Quality

Water Service Products

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Without crushing strength—or, for that matter—without all of the strength factors listed opposite—no pipe laid 100 years ago in *city streets* would be in service today.

But, in spite of the evolution of traffic from horse-drawn vehicles to heavy trucks and busses—and today's vast complexity of subway and underground utility services—cast iron gas and water mains, laid over a century ago, are serving in the streets of more than 30 cities in the United States and Canada.

Such service records prove that cast iron pipe combines all the strength factors of long life with ample margins of safety.

No pipe that is provably deficient in any of these strength factors should ever be laid in city streets.

Cast Iron Pipe Research Association,
Thos. F. Wolfe, Engineer, 122 So. Michigan Ave., Chicago 3.

CAST IRON PIPE

Strength factors of Long Life!

No pipe that is provably deficient in any of these strength factors should ever be laid in city streets

CRUSHING STRENGTH

The ability of cast iron pipe to withstand external loads imposed by heavy fill and unusual traffic loads is proved by the Ring Compression Test. Standard 6-inch cast iron pipe withstands a crushing weight of more than 14,000 lbs. per foot.

BEAM STRENGTH

When cast iron pipe is subjected to beam stress caused by soil settlement, or disturbance of soil by other utilities, or resting on an obstruction, tests prove that standard 6-inch cast iron pipe in 10-foot span sustains a load of 15,000 lbs.

SHOCK STRENGTH

The toughness of cast iron pipe which enables it to withstand impact and traffic shocks, as well as the hazards in handling, is demonstrated by the Impact Test. While under hydrostatic pressure and the heavy blows from a 50 pound hammer, standard 6-inch cast iron pipe does not crack until the hammer is dropped 6 times *on the same spot* from progressively increased heights of 6 inches.

BURSTING STRENGTH

In full length bursting tests standard 6-inch cast iron pipe withstands more than 2500 lbs. per square inch internal hydrostatic pressure, which proves ample ability to resist water-hammer or unusual working pressures.

SERVES FOR CENTURIES

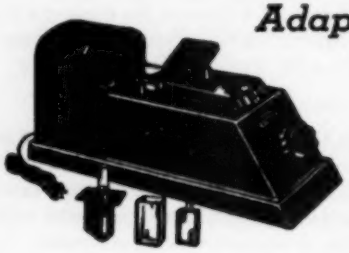
(*Continued from page 16*)

The old love and war combination recently got the Army Corps of Engineers all mixed up in the love life of the shad. Ignoring the old saw, Maryland fisheries' experts accused the Army of unfairness to the shad in proposing a Susquehanna River dam that would block the way to its spawning grounds. They called in Oregon fishery friends to support them in the contention that shad couldn't be coaxed or taught to climb ladders. But Col. Donald S. Burns, out at Bonneville Dam in Oregon, splashed through with a count of 255,260 shad that had climbed the ladders at Bonneville in the last dozen years and the Oregon testifiers were forced to admit that most Columbia shad didn't indulge in climbing because their regular spawning grounds were further downstream. With their point won, the Army men softened, too, to the point of conceding that some of the shad would probably be too lackadaisical to surmount such an obstacle. Anyway it's spring and, if love is all they say it is, no self-respecting shad would even need a ladder.

Walter H. Brown, formerly superintendent of the Cranston, R.I., sewage plant, has joined the staff of Builders-Providence, Inc., as sales engineer.

(*Continued on page 40*)

KLETT SUMMERSON
ELECTRIC PHOTOMETER



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Can be used for any determination in which color or turbidity can be developed in proportion to substance to be determined

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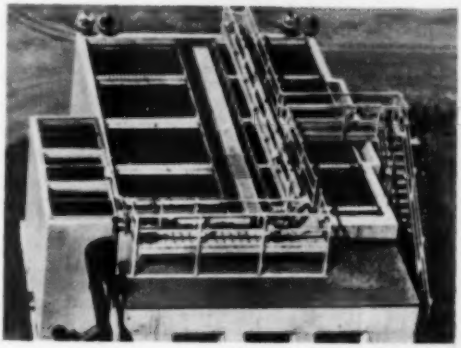

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1. Saves you up to 50% in space
2. Saves you up to 40% in chemicals
3. Saves you up to 75% in time
4. Short detention time
5. Uniform sludge filter
6. No settling of precipitates
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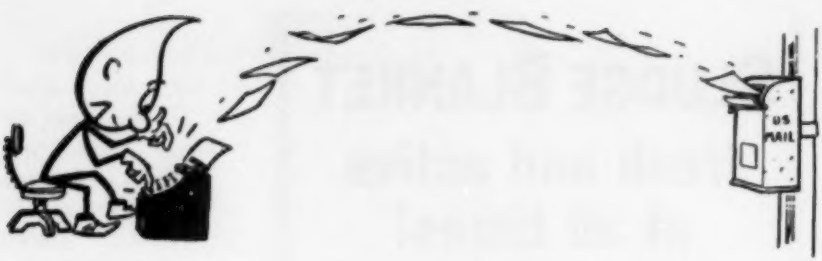

In a Family Way

To the Editor:

The water works family of Fredericksons have us all confused and I am going to attempt here to straighten out the family tree for my own records as well as A.W.W.A.'s. The February issue of the JOURNAL (P&R p. 18) has the two generations reversed, so perhaps the following will straighten things out:

Father: A. Frederickson, Pres. & Gen. Mgr., City Utilities Co., Pima, Ariz. (Oct. '49).

Son: A. Anton Frederickson, Pres. & Gen. Supt., Copper State Utilities Co. and Northern Water Utilities Co. (these two utilities located in the suburban area of Phoenix, known as Scottsdale); also Supt. of City Utilities Co., Pima, and General Utilities Co., Duncan, Ariz. (July '47).

Daughter: Margaret Frederickson, Asst. Mgr. & Secy.-Treas., City Utilities Co., Pima, and General Utilities Co., Duncan, Ariz. (Oct. '49).

I am certainly partially to blame for the confusion since I had carried the son's name on our books for years as "Jr.," only to find out now that he is not a junior, but simply A. Anton. I hesitate to add that there *is* an A. Anton Jr., who will be old enough in a few years to add another Frederickson to A.W.W.A. rolls. That might make the first case of three generations in A.W.W.A.

HELEN ROTTHAUS
Secy., Arizona Sec., A.W.W.A.
Phoenix, Ariz.; Feb. 23, 1950

To the Editor:

Re "Blood is thicker than water" (P&R p. 18, February, JOURNAL):

WILLIS BULLOCK (1844–1908). President of the Village of Canajoharie. Father of the present Municipal Water System of the Village of Canajoharie. Owner and editor of the *Hay Trade Journal*. Organizer of the National Hay Assn.

DANIEL WEBSTER SMITH (1853–1918). Water works operator for Johnson and Gring, Pa. With American Pipe & Construction Co. in New York, Pennsylvania, South Carolina and Alabama. Was Filter Plant Operator in Rock Hill, S. C., at the time of his death.

DEWITT H. BULLOCK (1889–). Superintendent Canajoharie Water Works from 1927 to date.

Willis Bullock and Daniel Webster Smith were respectively my father and father-in-law. I doubt if they were members of the A.W.W.A., however—especially Willis Bullock.

DEWITT H. BULLOCK
Supt., Water System
Canajoharie, N. Y.; Feb. 27, 1950

To Miss Rotthaus, thanks for recovering our Frederickson fumble and for keeping her A.W.W.A. eye on newly water-born prospects. To Mr. Bullock, thanks for conclusive evidence that water runs in the family even more quickly than blood. And to T. W. Thorpe, Pres. & Gen. Mgr., Thorpe Well Co., Des Moines, Iowa (Oct. '34), thanks for adding to our story with two sons—John W. and Thomas C.—whose enrollment as members is announced in this issue.—ED.

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Abul-Fetouh, Abdel-Hadi, Sr. Lecturer, Faculty of Eng., Farouk El-Awal Univ., Alexandria, Egypt (Jan. '50) *MR*

Al Kaem, A. Mahdi Ali, Student, San. Eng., Univ. of Michigan, 120½ E. Huron St., Ann Arbor, Mich. (Jr. M. Jan. '50)

Allin, Ralph W., Engr., Water Dept., 319 City Hall, Pasadena, Calif. (Jan. '50)

Baldwin, Robert T., *see* Chlorine Institute, Inc., The

Barrows, Harold Lyndon, John Wiley Jones Co., 1527 S. 3rd St., Terre Haute, Ind. (Jan. '50) *P*

Bastian, Leonard C., Tech. Director, Air Conditioning & Refrigerating Machinery Assn., Inc., 717 Southern Bldg., Washington 5, D.C. (Jan. '50) *R*

Blake, Herbert P., *see* Standard Elec. Time Co., The

Blew, Michael J., Col., Chief, Water Supply & San. Services Section, R & U, OCE, Washington 11, D.C. (Jan. '50) *MP*

Bowers, Addison Clement, Pres. & Gen. Mgr., Culligan Soft Water Service of San Diego, 2641 Kettner Blvd., San Diego 1, Calif. (Jan. '50) *PR*

Britton, J., Production Mgr., The Canada Valve & Hydrant Co., Ltd., Brantford, Ont. (Jan. '50)

Brown, Roger Chipman, Pres., Clarence Blair Assoc., Inc., 100 Crown St., New Haven, Conn. (Jan. '50) *PR*

Burris, George, *see* Greendale Munic. Water Works

Cast Iron Pipe Research Assn., Thomas F. Wolfe, Chief Engr., 122 S. Michigan Ave., Chicago 3, Ill. (Assoc. M. Jan. '50)

Chlorine Institute, Inc., The, Robert T. Baldwin, Secy., 50 E. 41st St., New York 17, N.Y. (Corp. M. Jan. '50)

Coker, Joe Ellis, Munic. Engr., Arkansas Inspection & Rating Bureau, 512 Hall Bldg., Little Rock, Ark. (Jan. '50) *M*

Colfax Munic. Water Works, H. V. Nugent, Supt., Colfax, La. (Munic. Sv. Sub. Jan. '50) *MP*

Cushing, Elliott M., Dist. Engr., U.S. Geological Survey, Water Resources Div., Ground Water Branch, Memphis General Depot, Memphis 2, Tenn. (Jan '50)

Davis, Edward Thomas, Partner, The Chester Engrs., 210 East Park Way, Pittsburgh 12, Pa. (Jan. '50) *MPR*

Dawson, Robert S., Service Mgr., West Virginia Water Service Co., 181 Summers St., Charleston, W.Va. (Jan. '50)

de Albear y Franquiz, Jesus Francisco, Chief Engr., Cuban Geodetic Section, Instituto Cartografico Nacional, Edificio Castro, Calle 25, No. 160, Vedado, Havana, Cuba (Jan. '50) *PR*

Edmonston, Arthur Donald, State Engr., Div. of Water Resources, Dept. of Public Works, Public Works Bldg., Sacramento, Calif. (Jan. '50) *MPR*

Ellsworth, City of, Ray A. Fried, Water Supt., Ellsworth, Kan. (Corp. M. Jan. '50) *MPR*

Fahlander, Lennart S., Salesman, Iowa Valve Co., 201 N. Talman Ave, Chicago Ill. (Jan. '50)

Frank, M. H., *see* Wisconsin Power & Light Co.

Franklin, Town of, J. L. Smith, City Mgr., Box 141, Franklin, Tenn. (Munic. Sv. Sub. Jan. '50) *MP*

Fried, Ray A., *see* Ellsworth, City of

Garden City, City of, Clinton P. Lightner, Supt. of Utilities, Garden City, Kan. (Corp. M. Jan. '50) *MPR*

Gardner, Walter A., San. Engr., Fieldcrest Mills, Spray, N.C. (Jan. '50) *P*

(*Continued on page 30*)

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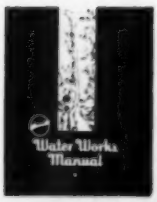

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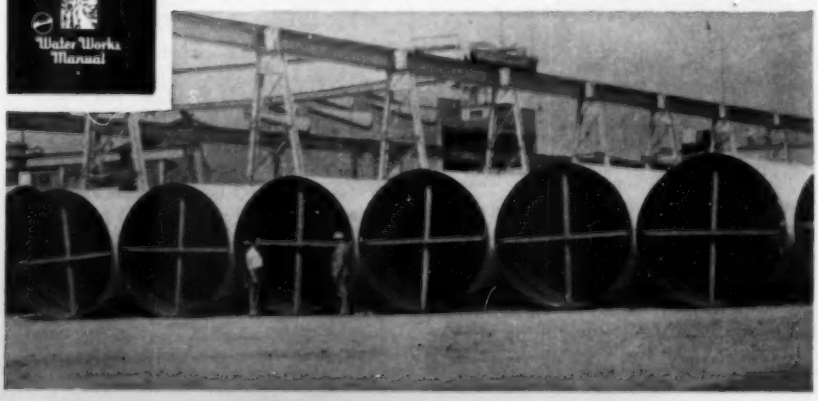

(Continued from page 28)

Gersbach, Henry, Foreman, Elec. & Water Dept., City Hall, Marshfield, Wis. (Jan. '50) *M*

Goldsboro, City of, Kermit N. Massey, Supt., Water Plant, City Hall, Goldsboro, N.C. (Corp. M. Jan. '50) *MP*

Gracey, Howard, *see* Hugoton, City of

Greendale Munic. Water Works, George Burris, Mgr., Lawrenceburg, Ind. (Corp. M. Jan. '50) *MP*

Grover, Charles, Water Works Engr., Water Works, 220 N. Charity St., Bethel, Ohio (Jan. '50)

Heath, Donald Murray, Service Engr., 1041½ S. Buckeye St., Kokomo, Ind. (Jan. '50) *M*

Heffner, Sam F., Supt., Water Dept., City Bldg., Bradford, Pa. (Jan. '50) *M*

Higbee, J. C., *see* Inter-Urban Area of Burlington-Nelson

Hill, Charles L., Supervisor, Billing & Meter Reading, West Virginia Water Service Co., 181 Summers St., Charleston, W.Va. (Jan. '50)

Holman, Raymond Carson, Collector-Investigator, Water Dept., Ft. Lauderdale, Fla. (Jan. '50) *M*

Hottinger, S. E., Jr., Munic. Engr., Louisiana Rating & Fire Prevention Bureau, 609 Canal Bank Bldg., New Orleans, La. (Jan. '50) *M*

Hugoton, City of, Howard Gracey, Supt. of Utilities, Hugoton, Kan. (Corp. M. Jan. '50) *MPR*

Inter-Urban Area of Burlington-Nelson, J. C. Higbee, Engr., Burlington, Ont. (Corp. M. Jan. '50)

Jenkins, Walter, Secy.-Treas., Kimball Bros. Co., Box 301, Council Bluffs, Iowa (Jan. '50) *M*

Jordan, J. L., Supervisor, West Virginia Water Service Co., 181 Summers St., Charleston, W.Va. (Jan. '50)

Kelley, Robert W., Jr., Cons. Engr., 16 Bay Villa Drive, Baytown, Tex. (Jan. '50) *MPR*

Kennedy, John J., Director of Water, 504 City Hall, Buffalo 2, N.Y. (Jan. '50) *M*

Kent, Charles L., Metallurgical Engr., Jones & Laughlin Steel Corp., 3rd Ave. & Ross St., Pittsburgh 30, Pa. (Jan. '50)

Kilbreath, Howard Emory, Supt., Public Works, Imlay City, Mich. (Jan. '50) *MP*

Kinsley, City of, Albert E. Wilson, City Mgr., Kinsley, Kan. (Corp. M. Jan. '50) *MPR*

Kirchman, Harry H., Prin. Civ. Engr., Blue Grass Ordnance Depot, Post Engr. Office, Richmond, Ky. (Jan '50) *MPR*

Larkin, Frances R. (Mrs.), Owner-Mgr., Culligan Soft Water Service, 725 S. Garfield Ave., Alhambra, Calif. (Jan. '50) *P*

Lee, Roderic B., Production Engr., Florida Power Corp., St. Petersburg, Fla. (Jan. '50) *P*

LePage, Albert J., San. Engr., Metropolitan Dist. Com., Water Div., Commonwealth Rd., Natick, Mass. (Jan. '50)

Leslie, Will Eddleman, Mgr., City Utilities, Box 337, Llano, Tex. (Jan. '50) *M*

Lightner, Clinton P., *see* Garden City, City of

Livingston City Council, Box 355, Livingston, Calif. (Corp. M. Jan. '50) *M*

Luoma, Merlyn George, Handyman, Grand View Hospital, Ironwood, Mich. (Jan. '50) *P*

Lyon Chemicals, Inc., D. B. Morris, Pres., 2305 Hampden Ave., St. Paul 4, Minn. (Assoc. M. Jan. '50)

Maley, Alexander B., *see* Sterne & Maley Co.

Mariani, A. S., Secy.-Treas., Mariani-O'Brien, Inc., 301—22nd St., S., St. Petersburg, Fla. (Jan. '50)

Massey, Kermit N., *see* Goldsboro, City of

Matthews, John Lepère, Mgr., City of New Castle Water Co., 31 N. Mill St., New Castle, Pa. (Jan. '50) *M*

Mojave Public Utility Dist., Fred Y. Wilkerson, Clerk, 401 K St., Mojave, Calif. (Corp. M. Jan. '50) *M*

Montel, Joseph I., Chem. Engr., Water Service Labs., Inc., 423 W. 126th St., New York 27, N.Y. (Jan. '50) *PR*

Moore, Robert E., Chief Operator, Canadian Celanese, Ltd., 606 Brock St., Drummondville, Que. (Jan. '50)

Morris, D. B., *see* Lyon Chemicals, Inc.

Nesheim, Peter, Supt., City Water Works, Williston, N.D. (Jan. '50) *MP*

Nier, Edward F., Comr. of Public Works, Dept. of Public Works, 34 Court St., Rochester, N.Y. (Jan. '50) *M*

Nugent, H. V., *see* Colfax Munic. Water Works

(Continued on page 32)

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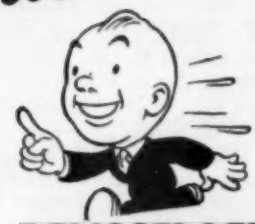

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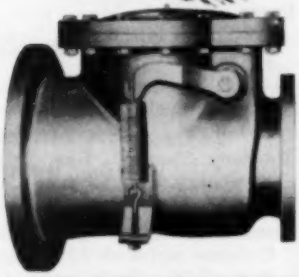

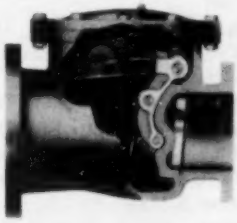

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(*Continued from page 30*)

O'Brien, J. C., Vice-Pres., Mariani-O'Brien, Inc., 301—22nd St., S., St. Petersburg, Fla. (Jan. '50)

Outhier, J. S., Mgr., Culligan Soft Water Service, 9621 California Ave., South Gate, Calif. (Jan. '50) *P*

Pang, A. K., Supervisor of Maint., Board of Water Supply, Box 3410, Honolulu 1, Hawaii (Jan. '50)

Parmelee, A. S., Sales Engr., Sackner Products, Inc., 901 Ottowa, N.W., Grand Rapids 2, Mich. (Jan. '50) *P*

Prado Pena, Manuel, Public Health Eng., Ministerio de Salubridad, Seccion de Ingenierio Sanitaria, San Nicolas No. 764, Havana, Cuba (Jan. '50) *PR*

Proske, H. O., Sales Engr., Rockwell Mfg. Co., 5635 Birch Ave., Mission, Kan. (Jan. '50)

Ragan, James L., Water Engr., Celanese Corp., Box 148, Bishop, Tex. (Jan. '50) *P*

Reid, L. Gordon, Water Comr., North East Borough, North East, Pa. (Jan. '50) *MPR*

Robinson, Harold I., Engr. & Vice-Pres., Pittsburgh Pipe Cleaner Co., 311 N. 20th St., Philadelphia 3, Pa. (Jan. '50)

Samuel, Ludwig E., Agricultural Attache, Embassy of Israel, 2210 Massachusetts Ave., N.W., Washington, D.C. (Jan. '50)

Schwindt, L. H., Mgr., L. H. Schwindt & Co., 37 King William St., Hamilton, Ont. (Jan. '50)

Smith, J. L., *see* Franklin, Town of

Standard Elec. Time Co., The, Herbert P. Blake, Vice-Pres., 89 Logan St., Springfield, Mass. (Assoc. M. Jan '50)

Sterne & Maley Co., Alexander B. Maley, Pres., 3604 S. Morgan St., Chicago 9, Ill. (Assoc. M. Jan. '50)

Stuart, Herbert W., Director of Quality Control, U.S. Pipe & Foundry Co., Burlington, N.J. (Jan. '50) *M*

Thorpe, John Wesley, Water Supply Contractor & Vice-Pres., Thorpe Well Co., 2340—6th Ave., Des Moines, Iowa (Jan. '50) *R*

Thorpe, Thomas Cope, Water Supply Contractor & Vice-Pres., Thorpe Well Co., 2340—6th Ave., Des Moines, Iowa (Jan. '50) *R*

Threlfall, James J., Supt. of Plant, Water & Light Dept., City Hall, Sturgis, Mich. (Jan. '50) *M*

Tohlin, Edgar T., Prin. Asst. Engr., Bureau of Water, Dept. of Public Works, 803 City Hall Annex, Philadelphia 7, Pa. (Jan. '50) *M*

Tongate, Ray E., Sales Eng., Thorpe Well Co., 2340—6th Ave., Des Moines, Iowa (Jan. '50) *R*

Unger, Gilbert C., Jr., Valuation Engr., Gannett Fleming Corddry & Carpenter, Inc., 600 N. 2nd St., Harrisburg, Pa. (Jan. '50) *M*

Van Hasselt, J. A. K. Estapa, Public Health Engr., State Health Dept., 1436 Dryades St., New Orleans, La. (Jan. '50) *P*

Vosburgh, George R., Engr., Dearborn Chemical Co., 501 C of C Bldg., Indianapolis, Ind. (Jan. '50)

Waverly, City of, Glen V. Yarger, City Engr., Waverly, Iowa (Munic. Sv. Sub. Jan '50) *M*

Weist, Herbert, Water Supt., Omah, Wash. (Jan. '50) *M*

Wilkerson, Fred Y., *see* Mojave Public Utility Dist.

Wilson, Albert E., *see* Kinsley, City of

Wisconsin Power & Light Co., M. H. Frank, Vice-Pres., 122 W. Washington Ave., Madison 1, Wis. (Corp. M. Jan. '50) *MPR*

Wolfe, Thomas F., *see* Cast Iron Pipe Research Assn.

Yarger, Glen V., *see* Waverly, City of

Young, Harold C., Dist. Engr., Wallace & Tiernan Co., Inc., 1911 McCall Rd., Austin, Tex. (Jan. '50) *MP*

Zubkoff, Seymour, Civ. Engr., Elson T. Killam, Hydr. & San. Engr., 140 Cedar St., New York 6, N.Y. (Jan. '50)

REINSTATEMENTS

Carver, Leon A., City Mgr. & City Engr., Chandler, Okla (Oct. '43) *M*

Gananoque Water Works Com., W. G. Tryon, Supt., Box 8, Gananoque, Ont. (Corp. M. Mar. '27)

Graver Water Conditioning Co., Henry T. Sulcer, Gen. Mgr., 216 W. 14th St., New York 11, N.Y. (Assoc. M. June '30)

(*Continued on page 34*)

IT'S ALWAYS OMEGA
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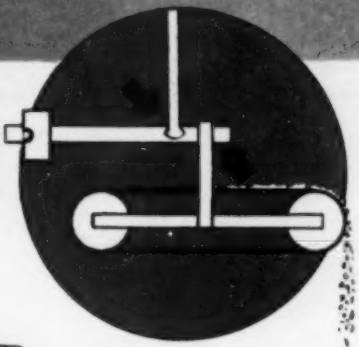

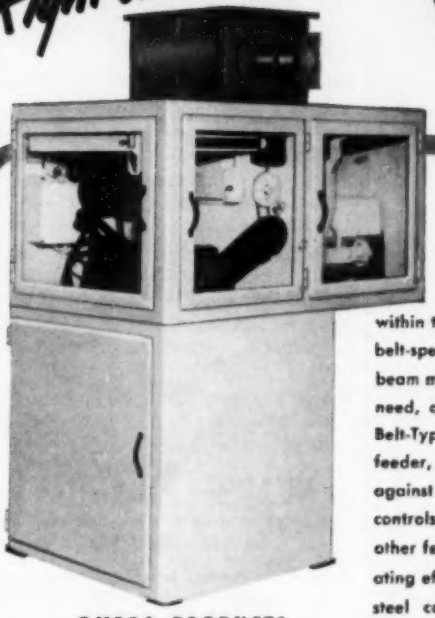

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THE LAST WORD IN FEEDERS

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(*Continued from page 32*)

Kovochich, Anton, Supt. of Filtration, Ford Motor Co., R.R. 1, Iron Mountain, Mich. (Jan. '46) *MP*

Nicklis, James A., Dist. Repr., Wallace & Tiernan Co., Inc., 3742 Tremont Rd., Columbus 12, Ohio (Apr. '39)

Sharts, Paul E., Tech. Service Div., Wallace & Tiernan Co., Inc., 280 Oakridge Ave., Summit, N.J. (Jan. '47)

Sulcer, Henry T., *see* Graver Water Conditioning Co.

Tryon, W. G., *see* Gananoque Water Works Com.

Wieters, A. H., Asst. Chief, Div. of Water Pollution Control, U.S. Public Health Service, Washington, D.C. (Nov. '21) *PR*

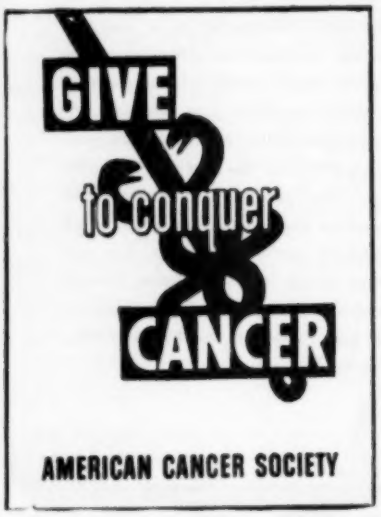
LOSSES

Deaths

Bromschwig, A. C., Sales Repr., Hersey Mfg. Co., 5605—11th Ave., S., Minneapolis 17, Minn. (Apr. '39)

Ellms, Joseph W., Comr. of Sewage Disposal, Dept. of Public Utilities, 103 City Hall, Cleveland 14, Ohio (Oct. '19) *Trustee '23-'25. P*

Febry, William E., Dist. Supt., Wisconsin Power & Light Co., 1707 Ashland Ave., Beloit, Wis. (Jan. '41) *M*



Hurd, Clarence E., Supt., Water Works, Punta Gorda, Fla. (July '37) *MPR*

Levy, A. G., Engr. of Constr. & Surveys, Div. of Water & Heat, Dept of Public Utilities, 604 Auditorium Bldg., Cleveland 14, Ohio (May '10) *MP*

Taylor, George R., Chemist & Bacteriologist, Scranton-Spring Brook Water Service Co., 135 Jefferson Ave., Scranton 3, Pa. (May '08) *P*

Resignations

Coca-Cola Export Corp., The, C. A. Shillinglaw, Vice-Pres., Technical Dept., 515 Madison Ave., New York 22, N.Y. (Corp. M. Apr. '45) *P*

Corfu, Village of, William Ehmann, Mayor, Water Dept., Corfu, N.Y. (Munic. Sv. Sub. Oct. '46) *M*

Costello, Charles Vincent, 24 Telegraph St., Binghamton, N.Y. (Affil. Jan. '41) *P*

Lightner, Clint, Supt. of Utilities, Garden City, Kan. (Apr. '48)

Murthy, N. Krishna, 182 Vanivilas Rd., Basavanagudi P.O., Bangalore, India (Jan. '48)

Priess, O. L., Sales Dept., Crane O'Fallon Co., 1601 Ulster St., Denver 7, Colo. (July '37)

Trout, Clarence L., Cincinnati Gas & Elec. Co., 323 Plum St., Cincinnati, Ohio (Jan. '39)

Wood, Thomas, Clerk, Borough of Pompton Lakes Water Dept., 9 Center St., Pompton Lakes, N.J. (Apr. '43)

CHANGES IN ADDRESS

Changes received between February 5 and March 5, 1950

Alizo C., Antonio, I.N.O.S., Acueducto de Maracaibo, Aurora 20, Maracaibo, Venezuela (Oct. '43)

Annen, Robert C., 12 Point View Drive, East Greenbush, N.Y. (Oct. '49) *MP*

Berkowitz, Sidney A., 40 Lee St., Cambridge 38, Mass. (Jan. '46) *P*

Carnahan, R. D., 703—2nd St., S., St. Charles, Ill. (Jan. '47)

Carroll, Thomas M., Mgr., Pump Dept., Fairbanks, Morse & Co., 4535 S. Soto St., Los Angeles 11, Calif. (July '49)

Casebier, J. P., Mgr., Munic. Water & Sewer System, Beaver Dam, Ky. (Oct. '48)

(*Continued on page 36*)

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(*Continued from page 34*)

Churchill, M. A., Public Health Engr., Tennessee Valley Authority, 640 New Sprankle Bldg., Knoxville, Tenn. (Jan. '49)

Clark, Horace L., Cons. Engr., Saco Rd., Box 61, Alfred, Me. (Apr. '30) *MPR*

Clifton, Harry Patrick, 45 Mount Prospect Grove, Clontarf, Dublin, Eire (July '47)

Colton, John H., Dist. Engr., Board of Fire Underwriters of Pacific, 510 S. Spring St., Los Angeles 13, Calif. (Jan. '49)

Cordle, Thomas Llewellin, Cons. Engr., 505 Alexander Ave., Morganton, N.C. (Jan. '43) *MP*

Daniels, J. Graham, Dist. Sales Mgr., Chicago Bridge & Iron Co., 550 W. 17th St., Box 687, Salt Lake City 9, Utah (Oct. '48)

Donnelly, Henry J., Supt., Water Board, 1018—15th St., Bellingham, Wash. (Apr. '49)

Eggers, John, San Jose Hills Water Co., 8620 S. Calmosa Ave., Whittier, Calif. (Oct. '48)

Firth, William J., Chemist, Water Dept., 20 Salem St., S.E., Roanoke, Va. (Jan. '43) *MP*

Ford, George A., Pres., Fairfax Hydraulics Water Co., 1461 Huntington Ave., Alexandria, Va. (July '47)

Fulkerson, Paul G., Chief Chemist, Filtration Plant, City Utilities, 1233 Somerset Lane, Fort Wayne, Ind. (Apr. '43) *P*

Gannon, Timothy J., 2028 Meridian Ave., South Pasadena, Calif. (July '49) *MP*

Graham, Howard E., Asst. Supt., Water Service, Illinois Central System, 8801 S. May St., Chicago 30, Ill. (Oct. '43)

Greenberg, Arnold E., 591 Williams Ave., Brooklyn 7, N.Y. (Jr. M. Jan. '49)

Hays, Paul J., City Engr., Minot, N.D. (Oct. '47)

Hendrix, D. A., Dist. Mgr., California Water Service Co., Box 48, Visalia, Calif. (Oct. '39) *M*

Johnson, W. H., Dist. Supt., Water Meter Div., Rockwell Mfg. Co., 7701 Empire State Bldg., New York 1, N.Y. (Jan. '49)

Kountz, R. Rupert, Assoc. Prof. of San. Eng., Pennsylvania State College, State College, Pa. (Apr. '41) *P*

Lamoureux, Marcel, Cons. Engr., 270 St. Laurence St., W., Longuevil, Que. (July '49)

Leonard, O. M., San. Eng. Consultant, 1000 Washington St., Michigan City, Ind. (Oct. '46) *MP*

Loop, Alfred B., Comptroller, Water Board, 2619 Franklin St., Bellingham, Wash. (Jan. '48) *M*

Lyon, Walter Alphons, San. Engr., Div. of Eng. Resources, U.S. Public Health Service, Washington 25, D.C. (Jan. '48) *P*

Mahapatra, Mrutyunjaya, Engr., Orissa, P.W.D., c/o Dr. Satyabadi Misra, Asst. Director, Public Health, Sekh Bazar, Cuttack, India (Jan. '49)

Mathisen, Harold M., Secy.-Gen. Mgr., La Habra Heights Mutual Water Co., 15703 Whittier Blvd., Whittier, Calif. (Jan. '46)

Maynard, Stuart B., 2796 Kenilworth Drive, Ann Arbor, Mich. (July '42)

McCulley, E. B., Supervisor of Utilities, Box 578, Cleveland, Tex. (Jan. '46)

McKay, W. G., Underwood & McLellan, c/o Town Hall, Flin Flon, Man. (Jan. '42) *P*

Mebus, George B., Cons. Engr., Northwestern National Bank Bldg., Glenside, Pa. (Apr. '48)

Moore, G. W., State Dept. of Health, Bureau of Environmental Sanitation, State Office Bldg., Albany, N.Y. (Apr. '37) *P*

Morris, Kenneth L., Mgr., South Bay Cons. Water Co., Box 89, Bayshore, N.Y. (Oct. '45) *M*

Mortensen, F. C., Col., SnC, APO 331, c/o Postmaster, San Francisco, Calif. (Apr. '40) *P*

Moutrey, Curtis E., Supt. of Filtration, Box 6005, Tulsa 6, Okla. (Jan. '47) *P*

Owens, James B., 2313 Homestead Drive, Silver Spring, Md. (Oct. '47)

Pequegnat, R. K., Water Com., City Hall, Kitchener, Ont. (Jan. '47) *MP*

Ray, Marvin E., City Supervisor, Municipal Bldg., Pullman, Wash. (Apr. '44) *M*

(*Continued on page 38*)

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(*Continued from page 36*)

Richards, Robert B., Box 312, Hightstown, N.J. (Jan. '43) *MPR*

Richey, L. G., 240 Sedgefield Rd., Charlotte 3, N.C. (Oct. '41) *M*

Rigling, Vance F., Div. Mgr., American Water Works Service Co., 928—3rd St., Harrisburg, Pa. (Apr. '43) *MP*

Satterlee, Don E., Mayor, 2829 Northwest Ave., Bellingham, Wash. (Jan. '48)

Schlott, Ralph, Supervisor of Distr., Water Works, 1013 Dueber, S.W., Canton 6, Ohio (July '39)

Scholz, Ted, Engr., Water Board, 2517 Cornwall Ave., Bellingham, Wash. (Apr. '49)

Stansmore, Keith C., The Dorr Co., Barry Pl., Stamford, Conn. (July '47)

Stewart, Charles M., 41 Congress St., Bradford, Pa. (July '35) *MPR*

Sydney Water Works, J. W. Carlin, City Engr., City Hall, Sydney, N.S. (Corp. M. Jan. '48) *MR*

Trager, Leonard W., Regional Drainage Basin Engr., U.S. Public Health Service, 120 Boylston St., Boston, Mass. (Jan. '46) *PR*

Tyler, Ralph L., 309 Front St., Riverton, N.J. (Jan. '37) *M*

Wallis, Robert Clinton, 3604 Cragmont St., Dallas 5, Tex. (Jan. '46) *M*

Weeks, James L., Mech. Engr. in Charge, Operating Div., Bureau of Eng., 811 N. Michigan Ave., Chicago, Ill. (Jan. '49)

Weinberger, Leon W., Dept. of Civ. Eng., Case Inst. of Technology, University Circle, Cleveland, Ohio (Oct. '47)

Wild, Harry E., Briley, Wild & Assoc., 550 N. Oleander Ave., Daytona Beach, Fla. (July '46) *PR*

Winder, John B., Chief Engr., Water Works, 2125 Commerce St., Dallas 1, Tex. (Oct. '35) *Director '36-'39. MPR*

Wittmer, Earl F., San. Engr., 806 Evening St., Worthington, Ohio (Oct. '47) *P*

Wolverine Tube Div., S. C. Seekell, Salesman, 412 Murray Bldg., Grand Rapids, Mich. (Assoc. M. Oct. '49)

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(*Continued from page 20*)

Anti-Climax is what we might well be accused of in calling the new fluoride removal plant at Britton, S.D., the *first* in the country (March P&R p. 2); and anticlimax again for now disillusioning you. Actually, out at Climax, Colo., ever since November 1937 they've been removing fluorides from softened filtered water by passage through contact beds of porous, granular tricalcium phosphate. Thus, of the 1,200 or more Climactics, we must beg humble pardon and plead not an over-, but an undersight, the plant being located some 11,500 ft. above sea level.

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Harold F. Werhane, formerly executive vice president, has been elected president of Culligan Zeolite Co. He succeeds Emmett J. Culligan, founder of the parent manufacturing organization for almost a thousand franchised soft water service dealers.

Frederick Ohrt, manager and chief engineer of the Honolulu Board of Water Supply won nomination as delegate to the Hawaii constitutional convention in primary elections held February 11. Finishing a strong third among a slate of eleven winners, Ohrt's chances for election in the run-off vote are considered good, as five delegates are to be picked for his district.

Two office managers have been appointed by De Laval Steam Turbine Co.—John Horth for the St. Louis office, which will operate as a direct factory branch, and H. H. Reynolds for Los Angeles.

(*Continued on page 42*)

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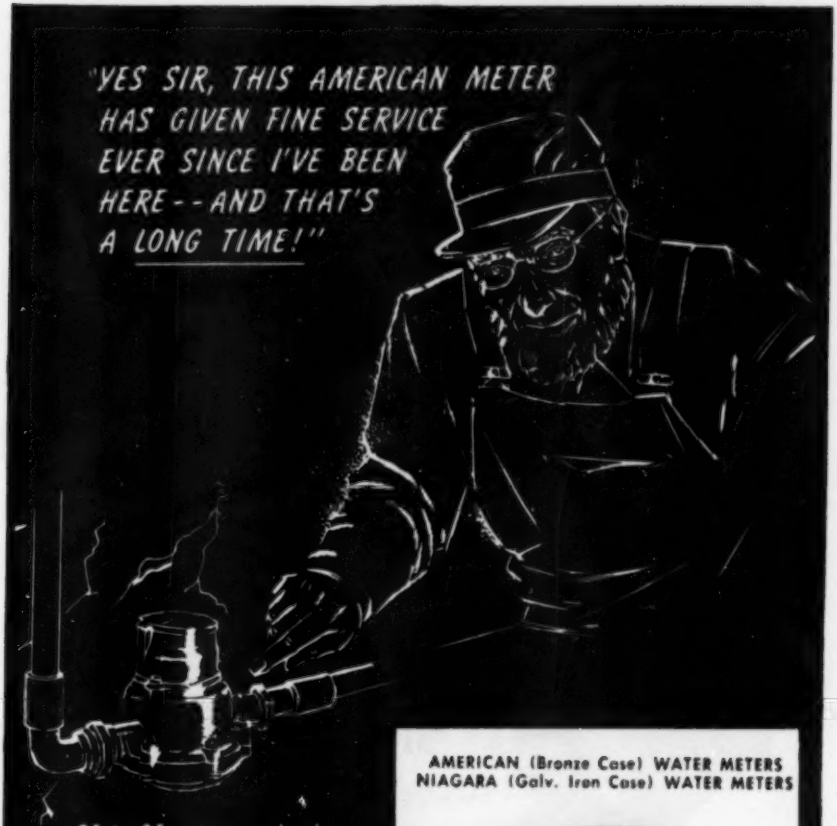

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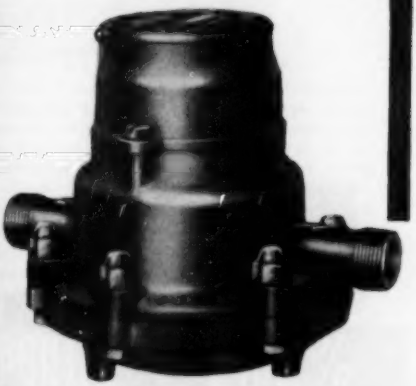

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(*Continued from page 40*)

A classification system for metallurgical information has been developed by the American Society for Metals, in cooperation with the Special Libraries Assn. Designed to code reports, pamphlets and clippings in logical and orderly fashion, the new system provides up to 181,000 different index headings when used with an inexpensive, hand-operated punch-card system. Beginning with the February issue, abstracts appearing in the society's publication, *Metals Review*, will be divided into 19 main categories, with symbols at the end of each abstract to place it more precisely in the classification system. Cards for use in coding material are in preparation, as is the publication of the system in book form.

A Water Policy Panel has been created by the Engineers' Joint Council to study the requirements for a sound national water policy, and make recommendations to the temporary Water Resources Policy Commission recently established by President Truman. Chairman of the panel and representative of the civil engineers is Wesley W. Horner. Richard D. Hoak represents chemical engineers; E. L. Clark the mining group; C. W. Mayott the electrical; and William F. Uhl the mechanical.

(*Continued on page 44*)

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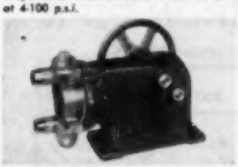

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(*Continued from page 42*)

Another outbreak of ten-ton thievery is in the offing. With the report of the theft, last December, of a Bucyrus-Erie 21-W water well drill from one A. R. Touvell of Aurora, Ill., the *Water Well Journal* recalled that only recently someone carried off a 100-ft. steel bridge in Alabama and nine miles of railroad track in Ohio. And it was only a couple years ago that we were reporting the pilfering of several pipelines—right out of the ground. The fact that these loots seem only petty larceny in comparison with theft, in the early Thirties, of three rather large apartment houses in Chicago does not make Mr. Touvell one bit happier. Of course, whoever stole his rig abandoned the truck on which it was mounted, and he has that as a consolation prize.

All of which makes us wonder when one of the hundreds of people who have bought the Brooklyn Bridge is quietly going to collect it. Anyway the serial number of Touvell's drill is 17758, so if you notice a 50-ft. shaft in your backyard some morning, be good enough to check it and let us know.

Herschell A. Lovelady has been appointed manager of sales for Standard Pipeprotection, Inc., with headquarters at 1411 S. Winston, Tulsa, Okla.

(*Continued on page 46*)

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THE WELSBACH CORPORATION

OZONE PROCESSES DIVISION

1500 Walnut St. Philadelphia 2, Pa.

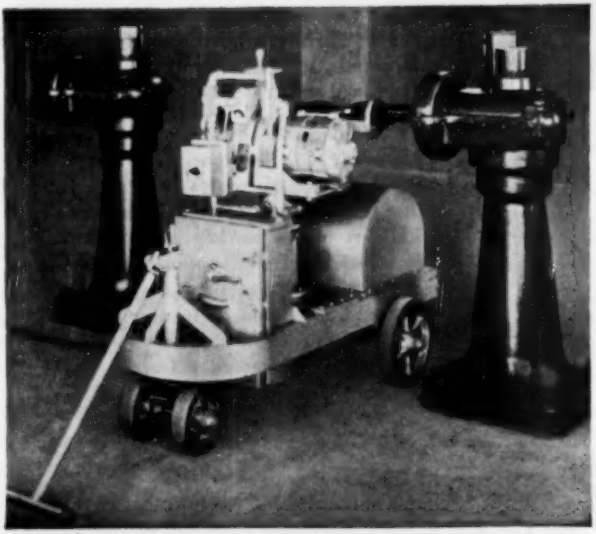
(*Continued from page 44*)

Howard S. Morse, executive vice-president of Indianapolis Water Co., has retired after nearly 25 years of management of the utility. He had been appointed manager in 1925, vice-president and general manager in 1938, and executive vice-president on March 4, 1949. The post of vice-president and general manager is currently being filled by Alfred O. Norris, formerly manager of the Birmingham, Ala., Water Works (*see* April 1949 P&R, p. 16). During his administration, Morse saw great increases in population served, metered services and consumption, and provided increased facilities to meet them. Twice a national director of A.W.W.A., he has also served on the Indiana Flood Control and Water Resources Committee and the Indianapolis Postwar Planning Committee.

Roy W. Morse has succeeded his father, the late W. C. Morse, as superintendent of the Seattle Water Dept. A graduate in civil engineering from the Univ. of Washington in 1928, he has had experience with the design of hydraulic equipment and, in consulting association with his father from 1933 to 1939, with the design and appraisal of water systems. For the past 10 years he was administrative and project engineer for Boeing Airplane Co.

(*Continued on page 48*)

LIMITORQUE "*PORTABLE*" VALVE OPERATOR



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Portable "LimiTorque" is equipped with famous *torque-limiting feature* (operates in Opening and Closing directions); *Limit switch* may be set for any travel (automatic resetting); *Universal Joint* connection for compensation of misalignment between floorstand and power unit.

This unique electrical valve operation is *another first* for Philadelphia. It embodies the salient and proven features that have made *"LimiTorque" Valve Operators* the most widely used in the world.

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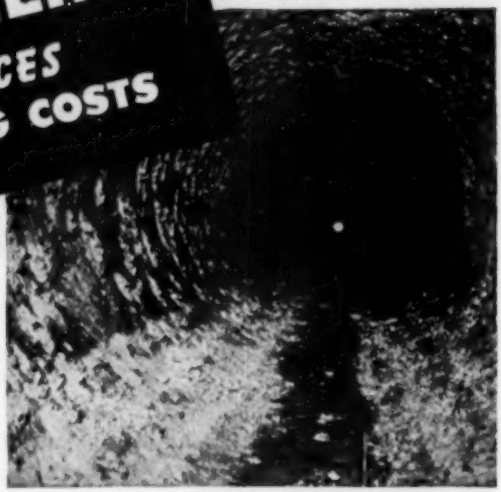

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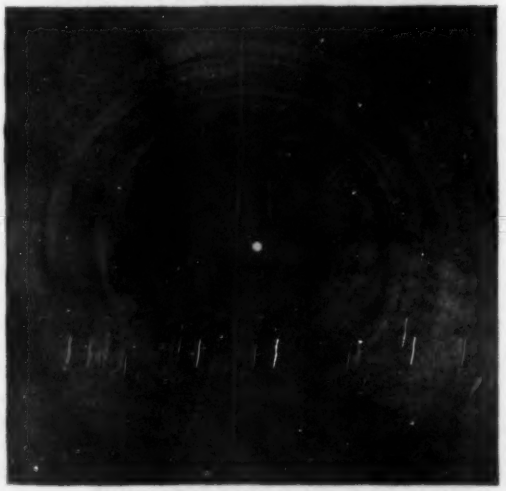
Protective cement mortar linings, as applied by Centriline, are continuous, dense, smooth, and without variation in quality. This ever-smooth surface permanently resists corrosion and tuberculation so that pumping expense and depreciation costs go down; coefficient of flow and useful life increases!

Whether old mains are losing efficiency or new projects are planned it is wise to consider Centrilining for the sake of the municipal budget. Our competent staff of hydraulic engineers is ready to assist you at any time.

▶ PIPE LINING FACTS NO. 2 ◀



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CEMENT MORTAR LININGS FOR WATER MAINS

Centrifugally Applied in Strict Conformity with A.W.W.A. Specifications

(*Continued from page 46*)

The recent freeze-up of a 1,200-ft. bridge-crossing section of a 10-in. pipe, cutting off the water supply of Eastport, Me., makes all the more remarkable the story of Flin Flon, Manitoba, where service is maintained through aboveground mains despite 40-below weather. Flin Flon's flow secret, which waterless Eastporters may well want to learn, is the injection of steam into its lines, the encasement of the pipe in wooden boxes filled with wood shavings and the use of return lines on its services to guarantee constant flow. Of course, that's rather strong medicine for a sporadic malady, and the news that even Flin Flonners are planning now to bury their pipe lessens the lesson, so we'll leave Supt. Staples to his own thawts.

Meanwhile, however, the fact that it was cold in the East ought to be apparent from an *Associated Press* dispatch out of Buffalo, N.Y., where workers in a coal yard built a fire under a gondola to thaw a frozen shipment of that then strike-bound commodity so they could unload it. The fire, of course, ignited the coal. Water then entered the picture to put out the fire—and refroze the coal. But this is where we came in.

Syntron Co. has moved its New York sales and engineering office from the old Long Island City location to 1860 Broadway, New York 23. The phone number for the new Manhattan office is JUdson 6–1507.

With the completion of operational tests, Carter Products Corp. has placed on the market a new, semi-rigid extruded plastic pipe, designated Carlon "T." Guaranteed against rot, rust, electrolysis or galvanic coupling, the pipe is light and easily handled. In addition, the elasticity of the pipe wall will permit water within it to freeze completely without bursting or damaging the pipe. Pipe sections are connected by plastic sleeves which are first treated with a special cement and then slipped over the ends to be joined. Threaded plastic sleeves permit coupling of plastic services to metal pipe equipped with standard fittings. Size ranges from ½ to 2 in. come in random 20-ft. lengths.

(*Continued on page 50*)

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NO two corrosion problems are exactly alike — that's one reason stereotyped solutions won't work. Cathodic protection, properly engineered and applied, is economical, effective and practical. E.R.P. offers preliminary engineering, design, equipment and installation services for an individual solution to each particular problem. For data on cathodic protection of structures from pipe lines to elevated tanks, call on E.R.P. without obligation.

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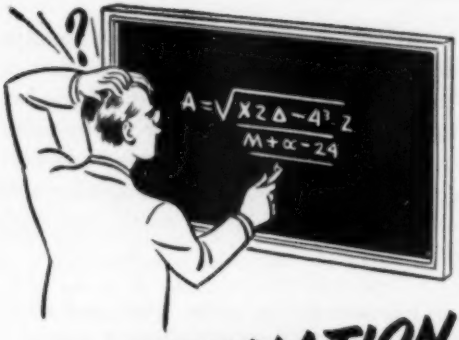

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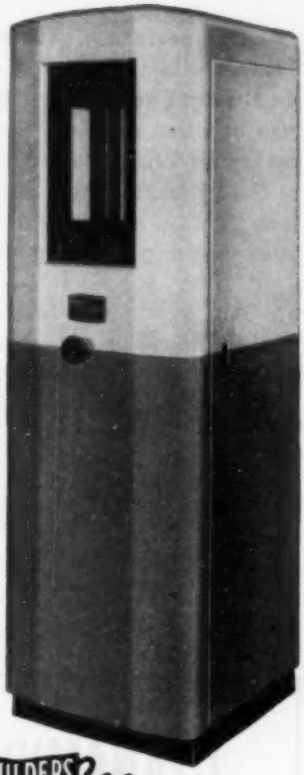
Simplicity means safety, too. The powerful, spring-loaded chlorine control valve delivers the exact amount of chlorine required — yet is ready to stop the flow instantly, if any condition occurs to interfere with *safe* operation. It will pay you to learn more about these and the many other advantages of Builders Chlorinizers: for manual, semi-automatic, program, or flow-proportional chlorination. For Bulletins and engineering information, address Builders - Providence, Inc. (Division of Builders Iron Foundry), Providence 1, R. I.



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BUILDERS PROVIDENCE

Instruments

(Continued from page 48)

Engineers are gentlemen! At any rate, engineers prefer blondes. That is to say, production engineers of the Friez Instruments division of the Bendix Aviation Corp. prefer blondes. Anyway, the 216 in. of fine human hair that goes into the "Hygrodial," a new hygrometer-thermometer put out by Friez, is blond, because blond has been found the most sensitive to changes in the atmospheric moisture content. And any engineer who hasn't noticed that blondes have their hair up in curlers more often than other women really is a gentleman.

An "inside-out" flashlight cell has been developed by National Carbon Div. of Union Carbide & Carbon Corp. Making the container of carbon—heretofore the core—instead of zinc, and putting a zinc power vane in the middle, makes these Eveready "batteries" leak- and corrosion-proof, with consequent elimination of danger to equipment they power. The new industrial cell—No. 1050—is also said to provide more than twice the usable light of previous cells. The makers emphasize that size standardization makes it interchangeable with all D-size cells (standard flashlight), but of course one must keep the reversed polarity in mind.

CYANAMID sulfate of alumina

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- Removal of Suspended Impurities
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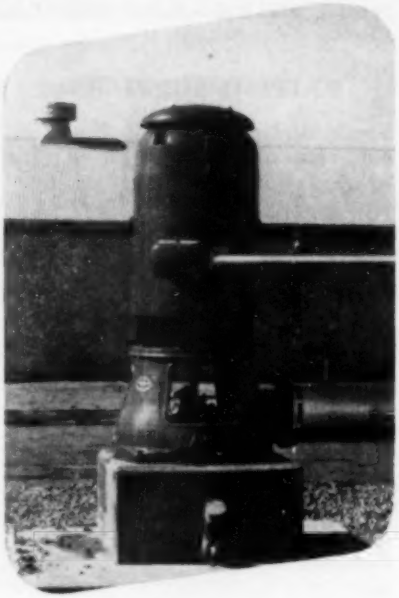

When you buy a Layne Well Water System or a Layne Vertical Turbine Pump, you are getting the assurance that if Layne equipment does not make good —the Layne Organization will!

DOING THE JOB COMPLETE!

Layne's planning supplements that of your own engineers, but Layne's work is complete from the test well to the finished, and in operation units—proven in production volume and fully adjusted for the task to be performed. Such a service is widely welcomed by the Nation's greatest—and sometimes smallest cities and industrial plants. It is an over-all service that saves time and gives universal satisfaction. For further information, literature, etc., address

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WELL WATER SYSTEMS

Condensation

Key: In the reference to the publication in which the abstracted article appears, **39**:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, **39**:5:1 (May '47) indicates volume 39, number 5, page 1, issued dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *B.H.—Bulletin of Hygiene (Great Britain); C. A.—Chemical Abstracts; I. M.—Institute of Metals (Great Britain); P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research (Great Britain).*

BRITISH SUPPLIES

South Wales Water Supplies—Cardiff, Newport and Taf Fechan Works. ANON. Wtr. & Wtr. Eng. (Gt. Br.), **52**:324 (July '49). Taf Fawr works from which Cardiff derives supply comprises Cantref Res. (323 mil.gal. (Imp.)), Beacons Res. (345 mil.gal.) and Llwynon Res. (1211 mil.gal.). At first water from Taf Fawr discharged to storage reservoirs near Cardiff and there filtered. Later decided to install filters at Cantref, where water now passes through screening chamber and turbine generator to conditioner, at which point it receives dose of sodium aluminate. Flocculation and clarification take place in 2 spiral clarifiers and water then flows to 12 rapid gravity filters. Talybont reservoir, for Newport, has catchment area of 6,000 acres and avg. rainfall of 68½". Filter plant has 18 rapid filters, each 8' in. diam. and 27.5' long. Water fed from Talybont to lower-level area of Newport, 35 mi. away, through 25-in. cast-iron pipe. High-level zone supplied from 2 other impounding reservoirs. Taf Fechan Reservoir third largest in Wales, with capac. of 3400 mil.gal. Distinctive feature is shaft spillway, 16' in diam., which terminates nearly 100' below top water level in 13"-diam. outlet tunnel. Water treatment plant comprises screens, automatic dosing gear for sulfate of alumina and lime, 12 Paterson gravity filters, and chloramination plant, with rated output of 7.5 mgd. (Imp.).—*H. E. Babbitt.*

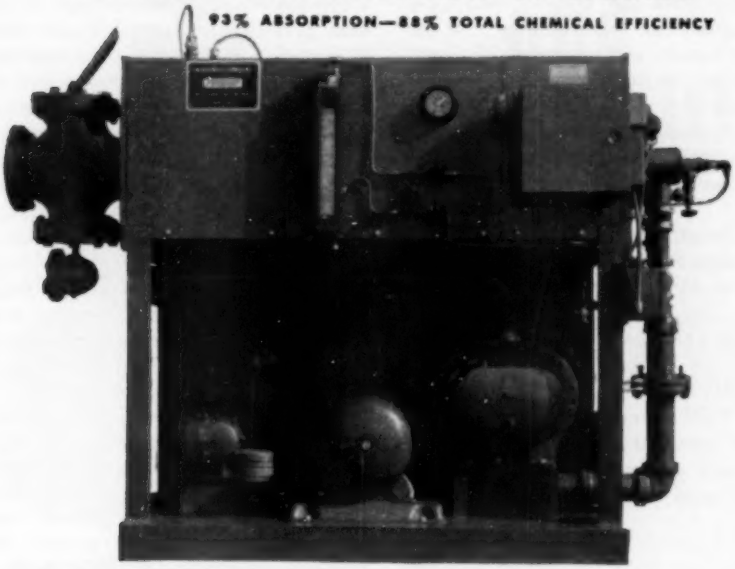
Ashford Common Works. Progress on London's Gigantic Filter Station. ANON. Wtr. & Wtr. Eng. (Gt. Br.), 52:381 (Aug. '49). Works estd. to cost nearly £4,500,000 designed to filter 90 mgd. (Imp.) and in addn. to pump 200 mgd. (Imp.) from Queen Mary storage reservoir. Site occupies about 125 acres between Queen Mary Res. and aqueduct which brings water from storage reservoir at Staines to filtration plant at Kempton Park works. Water will gravitate or be pumped to microscreens or primary filters. Each screen will be 10' in diam. and 10' long, with gunmetal frames covered with fine stainless-steel woven fabric giving 46,000 holes per sq.in. Screens will be motor-driven with linear speeds 20, 35 and 50 fpm. From microscreens or primary filters, water flows to 32 slow sand filters, each 300 × 112', designed to operate at max. rate of 4 gal. (Imp.) per sq.ft. per hr. Filtering medium will be sand, graded to high uniformity coefficient, 2'3" thick, supported on 3" of fine gravel. Flow of water to each batch of 16 filters will be controlled automatically by 54" needle valve in pipeline on upstream side of aeration basins. Water carried from filters by two 66"-diam. mains to chlorinating points and thence to contact-and-balancing tanks. Superchlorination will be used, in excess of breakpoint. Dirty sand will be removed from filters by hand and transported to plants where it will be washed and stored. Gravel subsoil under filters and contact beds has been stabilized by being first loosened, then

(*Continued on page 54*)

CARBALL CO_{TWO} UNIT...

SPECIFICALLY DESIGNED FOR THE CLEAN, EFFICIENT CARBONIZATION OF LIQUIDS

93% ABSORPTION—88% TOTAL CHEMICAL EFFICIENCY



- A CO_2 producer that *COMPLETELY* burns GAS or OIL.
- Produces the highest percentage of CO_2 gas with no CO or condensible carbon.
- Completely eliminates oil scum . . . no taste imparted to potable waters.
- No scrubbers or filters required.
- Compressor handles clean, cold air only. The fuel is burned under sufficient pressure to cause deep diffusion directly from the producer.
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- A factory-tested, package unit with air compressor, fuel pumps and appurtenances mounted on one frame.
- 50% more chemical efficiency than any other method in current practice.

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WALKER PROCESS EQUIPMENT INC.

FACTORY • ENGINEERING OFFICES • LABORATORIES

518 HANKES AVENUE • AURORA, ILLINOIS

PROQUIP

(*Continued from page 52*)

mixed with Portland cement at rate of 50 lb. per sq.yd. Water then added to optimum compaction amt. Plant to be powered by electricity furnished by Southern Electric Board, with power standby from gas turbines and diesel alternators for peak-lopping. Water works history will be made with installation of combustion-turbo-alternators for standby power supply to water works pumping station. Working of station will be controlled by operator from control room.—*H. E. Babbitt.*

The Treatment of Doubtful Waters for Public Supplies. NORMAN J. PUGH. Wtr. & Wtr. Eng. (Gt. Br.), **52**:73 (Feb. '49). Beneficial results of free residual chlorination have been established (at Ryton Water Works) but difficulty of obtaining free chlorine with high ammonia content in raw water prevented advantages of free available chlorine being obtained continuously. Small-scale expt. had given evidence that by passing raw water through bact. filter, reduction in free and saline ammonia content by oxidation could be expected. Generally, filter has not only fulfilled original purpose but has shown added advantages. Bed has proven to be self-sloughing. In oxidation of ammonia, filter has been effective over full range of its operation. Results through filter show substantial overall improvement in reduction of nitrite content. General tendency has been to stabilize pH value of water for further treatment. Taste-producing phenols have been elimd. by biologic action. Application of small doses of phenol to raw water passing through filter did not impair normal processes of nitrification. Small concns. of phenol at first applied at once removed by biologic action. Concns. up to 1 ppm. readily removed and considerable reductions evident when concn. of phenol exceeded this figure. Unlikely that such relatively high concns. as 1 ppm. would ever be present in raw water. Concns. of phenol and related monohydric phenols effectively removed by passage through biol. filter. Comparative coagulation tests of raw and pretreated water indicate that flocculation easier after pretreatment. Prechlorinated and settled water almost invariably of such appearance as to permit its being passed into supply without further treatment. Claimed that potable water is provided after first stage of normal water works treatment. Factors which had influenced treatment procedure prior to '45 were immobilization of euglena and desire to obtain long period of contact with ammonia for destruction of dangerous bacteria. Application of chlorine near intake appeared to improve conditions in sedimentation tanks. Conclusion: [1] biol. pretreatment of waters from doubtful sources appears to offer great advantages; [2] sedimentation stage in modern water works practice may be expected to assume greater importance, possibly at expense of filtration; [3] destruction of harmful bacteria should be featured at as early stage as possible in sequence of treatment; [4] chlorine effective and reliable means of destroying harmful bacteria, but to be fully effective it should be used in free available state; [5] only by reference to long-period records of characteristics of raw water can necessary treatment works be designed to combine safety and economy; [6] as prelim. to major water treatment scheme, it is desirable to operate pilot plant; and [7] inevitable admission of more doubtful raw waters as potential sources for public water supplies demands broader approach to water treatment research problems than has been necessary when considering safeguarding more consistent and reliable sources which have been treated in past.—*H. E. Babbitt.*

(*Continued on page 56*)

Bury it and Forget it!

If you will think before buying a valve—you can eliminate thinking of it forever after. When you think of valves—think of the years of time and effort we have put into giving you a smooth-operating, trouble-free valve. Think of the progressive water works men who have relied on Eddy Valves for years—then specify and insist on getting Eddy Valves—you can bury them and forget them.

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GATE VALVES
Since 1869 EDDY For Long Service

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(*Continued from page 54*)

CANADIAN SUPPLIES

Build New 15-mil.gal. Water Treatment Plant at Edmonton [Alta.]. W. J. McFARLAND. Eng. Cont. Rec. (Can.) **62**:4:98 (Apr. '49). North Saskatchewan R. water clarified and softened by treatment with CaO, Na_2CO_3 and alum in plant providing 2-stage flocculation, clarification and recarbonation, and filtration. Sludge returned to influent from first clarifier. River water very turbid during high-water periods, hardness up to 350 ppm. Final hardness 75 ppm. CO_2 for recarbonation by burning natural gas.—*R. E. Thompson.*

New Feeder Mains, New Garage, FM Radio Among Winnipeg [Man.] Water Works Improvements. W. L. WARDROP. Eng. Cont. Rec. (Can.) **62**:4:86 (Apr. '49). Developments include Kardex system for 50,000 services and 2-way radio communication with 18 mobile units and 1 fixed station. Mains total 333 mi.—*R. E. Thompson.*

Halifax [N.S.] Builds New Automatic Chlorinating Station. ANON. Eng. Cont. Rec. (Can.) **62**:4:92 (Apr. '49). Bldg., 66 × 22′, divided into operators' office, machine and scale rooms, between which are large air-tight plate glass windows. Equip. includes 5 chlorinators, overhead cranes for handling 150-lb. cylinders, Cl recorders and ventilation system. Cost approx. $250,000.—*R. E. Thompson.*

Reconditioning of Water Works Standpipe at Ingersoll, Ont. R. D. McCOLLUM. Wtr. & Sew. (Can.) **86**:3:21 (Mar. '48). Standpipe used as combined aerator and storage tank for strongly sulfurous water badly corroded. Tank repaired, tubercles, rust and scale removed by flame priming and power brushing and protective coating applied while metal warm. Flame priming effected with torch giving series of closely spaced, high-velocity, oxyacetylene flames of extremely high temp. (6300°F.). No-Ox-Id protective coatings used inside and outside.—*R. E. Thompson.*

Urgent Need for Complete Treatment by Grand River [Ont.] Municipalities. A. E. BERRY. Wtr. & Sew. (Can.) **87**:9:36 (Sept. '49). All sewered municipalities on Grand R. and tributaries except 2 have sewage treatment plants, but only 2 provide other than primary treatment. Conservation scheme, which included constr. of Shand Dam, has made water available to offset low summer flows but increased pop. and water consumption and expanded industrial activity have affected stream adversely. High

(*Continued on page 58*)

PALMER *Filter Bed* AGITATORS

Prevent Sand Beds From Cracking
Eliminate Mud Balls
Save Wash Water
Lengthen Filter Runs
Higher Rates of Filtration

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THAT'S ALL

Hydro-tite, the self-caulking, self-sealing, pipe-jointing compound, solidifies and hardens immediately without shrinkage. No caulking is necessary. Any slight seepage that may appear at first soon stops.

For over thirty years Hydro-tite has proved its ability to stand up under all conditions of strain, vibration and pressure. Send for data book and sample.

ALWAYS USE FIBREX

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Works: West Medford Station, Boston, Mass.

(*Continued from page 56*)

temp. and low rainfall of past summer also unfavorable. Coliform concns. as high as 10,000,000 M.P.N. per 100 ml., O contents as low as 1.5 ml. per l. and B.O.D. values up to 16 ppm. found. Sewage treatment and diln. provided not sufficient to maint. stream in good condition. Plant effluents contained up to 1 bil. coliforms per 100 ml., 1664 ppm. suspended solids and 760 ppm. B.O.D. Complete treatment, including chlorination, of all sewage and wastes discharged and full utilization of diln. provided by present and future storage dams only remedy for situation.—*R. E. Thompson.*

Expansion Carried Out by Sudbury [Ont.] Water Works System. R. H. MATINDALE. Eng. Cont. Rec. (Can.) **62**:4:78 (Apr. '49). Supply derived from Ramsay Lake through 2 intakes, 18″ and 30″ in diam., extending 1000′ into 65′ depth. Temp. 34–56°F. Duplicate chlorinators for disinfection. Consumption by 45,166 pop. 2.71 mgd., equiv. to 60 gpd./cap. In '48 gross revenue $173,418.73 and expenditures $167,950.69, excluding capital improvements. Latter included pumping station contg. 3 motor-driven turbine pumps (total capac. 6600 gpm.) and 2 gasoline engine-driven units (2800 gpd. each), 0.5-mil.gal. elevated radial cone tank supported on tubular columns (cost $83,000) and main extensions.—*R. E. Thompson.*

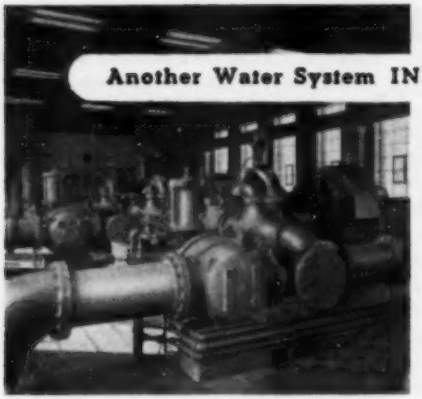
Welded Steel Water Main Laid in Toronto to Increase Pressure in Northern Section. R. J. ANDERSON. Eng. Cont. Rec. (Can.) **62**:10:71 (Oct. '49). New main to high-level part of city consists of 12,100′ of 45″ (id.) steel pipe, lined with 1½″ cement-mortar on wire mesh welded to pipe and encased *in situ* with 4″ concrete. Cost about $1,400,000. Pipe fabricated in 30′ lengths from 4 plates $\frac{7}{16}$–$\frac{9}{16}$″ thick by "Unionmelt" machine-welding process, which is described. Indicated strength in weld area 60,000 psi.; hydrostatic pressures up to 230 psi. withstood. Similar 48″ main, laid in '38 and opened twice for addns., found in as good condition as when installed. Estd. life may reach 200 yr.—*R. E. Thompson.*

HEALTH AND HYGIENE

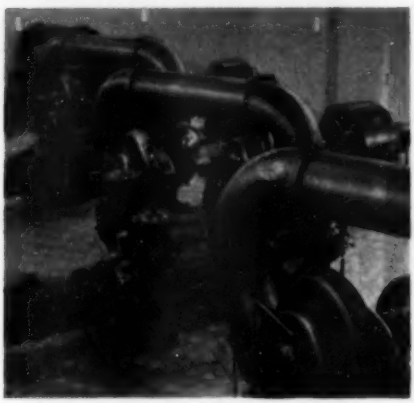
Poliomyelitis and Standard Methods of Water Treatment. JAN JUST. Gaz, Woda i Tech Sanit. (Poland) **23**:44 (Feb. '49). Review of epidemiology of polio virus presented along with various possible modes of transmission including water. Virus more resistant to physical and chem. agents than other organisms of intestinal tract. Since studies have indicated that virus may be found in both natural waters and sewage, essential to evaluate present methods of water treatment and sewage disposal and their effect upon fate of virus, and whether present criteria of approving waters adequate. Unlike other enteric diseases, polio epidemics associated with countries having high std. of living. Two possible assumptions suggested: [1] that sanitary facilities, water, etc., have nothing in common with spread of polio; and [2] that available methods of preventing epidemics of communicable diseases of intestinal tract through rational protection and constr. of sanitary facilities insufficient to control polio. American authors cited as stating that usual methods of water treatment do not inactivate virus of polio, although other authors indicate that 0.05 ppm. "free" chlorine after 10-min. contact will inactivate organisms, provided pH in range of 6.85–7.4. At pH 8.95–9.24 organisms will not be inactivated after 1-hr. contact with 0.05 ppm. of free chlorine or 0.45 ppm. of chloramine. Until addnl. studies made, impossible to state amt. of free chlorine or chlo-

(*Continued on page 60*)

Another Water System INSTALLS DE LAVAL PUMPS*



Pumps at the Junction Station Note provision on bed plates for addition of second pump in series to increase head from 150′ to 300′.



Pumps in series at the Whitestone Station. Three of the units have a capacity of 20 mgd and one a capacity of 10 mgd—all against 300′ head.

De Laval Pumps Deliver Water

80 Miles

The cities of Saginaw and Midland, Michigan, receive water from a point 80 miles away in Lake Huron, the closest source of potable water in adequate quantity,

Two pumping stations, the Whitestone Point Station and the Junction Station, serve this entire supply line. The Whitestone Station is equipped with four De Laval pumping units having a combined capacity of 70 mgd against 300′ head. Each of these units consists of two pumps in series.

The Junction Station is likewise equipped with four De Laval pumping units having a combined capacity of 70 mgd. At present, each of these units consists of a single pump operating against 150′ head, provision having been made for the addition of pumps in series in order to double the total delivered head, if necessary.

78% of all American cities of over 100,000 population use De Laval water works pumps.

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TURBINES · HELICAL GEARS · CENTRIFUGAL BLOWERS AND COMPRESSORS
CENTRIFUGAL PUMPS · WORM GEAR SPEED REDUCERS · IMO OIL PUMPS

(Continued from page 58)

ramine required to guarantee inactivation of polio virus.—*Conrad P. Straub.*

Infected Cooling Water and Its Effect on Spoilage in Canned Foods. T. E. BASHFORD. Proc. Soc. Applied Bact. (Gt. Br.), 1:46 ('47). Author refers to earlier work which shows influence of contamd. cooling water upon incidence of spoilage in cans. Very often only highly contamd. water available for cooling and obvious remedy chlorination of such waters. Author submits table made during one year in regard to water as received at one cannery and same water after chlorine treatment. Many different packs used and over 40,000 cans cooled. Bacteria introduced from infected water through minute leaks show wide range, but almost invariably include nonsporing types of low heat resistance. This fact utilized in test in which such typical organism as *Aer. aerogenes* added in large numbers to cooling water and by estimation of extent of its introduction into cooled cans, efficiency of seam constr. assessed.—*B. H.*

WATERSHED CONTROL

The Silt Problem at Spring Lake [Macomb, Ill.]. Report of Investigation No. 4. J. B. STALL, L. C. GOTTSCHALK, A. A. KLINGEBIEL, E. L. SAUER & E. E. DETURK. State Water Survey Div., Urbana, Ill. (1949). Spring Lake, munic. water supply reservoir at Macomb, Ill., built in '27 at cost of about $138,000. Lake has drainage area of 20.2 sq.mi.; original surface area 84.3 acres and original vol. 607 acre-ft. '47 sedimentation

(Continued on page 62)

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FERRIC SULPHATE
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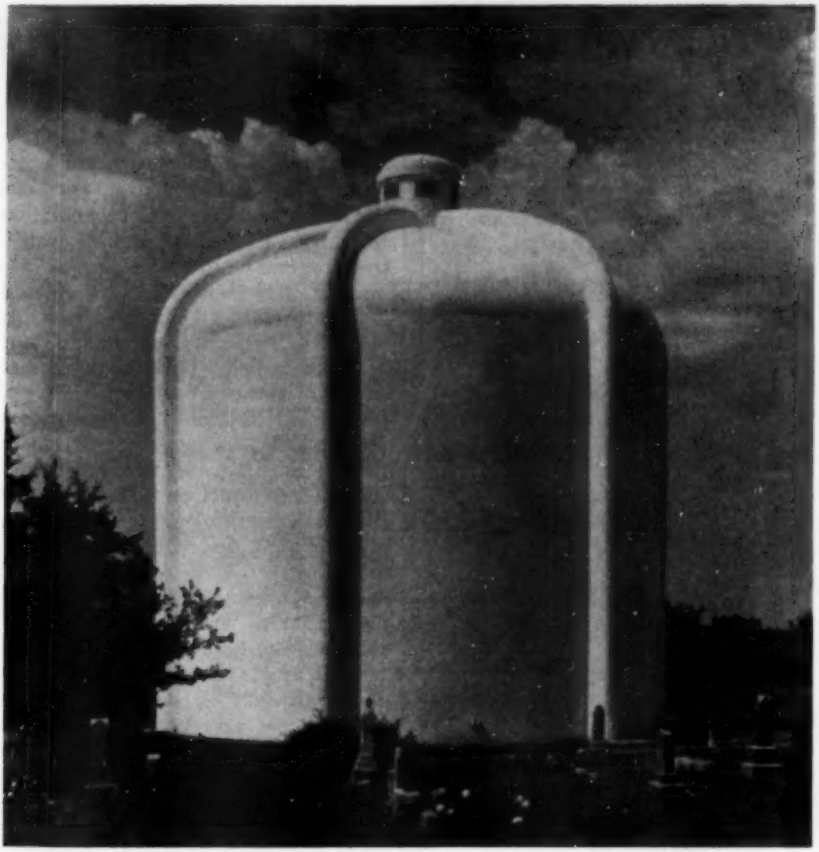
726 Reserve Loan Life Bldg.....DALLAS 1
NEW YORK 17.....101 Park Avenue

(Continued from page 60)

survey shows capac. loss of 2.32% per year. In 20.4 yr. reservoir has been in existence it has lost 47.3% of original capac. At this rate, lake would be practically full of silt in another 20–25 yr. Most serious drawdown experienced in 20.4 yr. removed vol. of water from lake equal to approx. ⅛ of lake's original capac. or ¼ of present capac. Anal. shows that since storage capac. decreasing and water demand in Macomb increasing, reservoir will be inadequate by '53 to furnish full needs of city in event of severe drought. Present water consumption in Macomb approx. 63 gpd./cap., which is lower avg. consumption than in several other representative cities in Illinois utilizing surface reservoirs for source of supply. 14.23 acre-ft. of sediment deposited in Spring Lake every year represents destruction amtg. to $3200 of original cost of constr. of reservoir. At '48 price levels, it would cost approx. $7500 annually to replace storage capac. lost to sediment each year in Spring Lake. As originally designed and built, Spring Lake had ratio of capac. to watershed (*C/W* ratio) of 30 acre-ft./sq.mi. Sedimentation investigations in recent years in U.S. and in Illinois indicate that reservoir of this size in Illinois should have *C/W* ratio of at least 150 acre-ft./sq.mi. for life of 100 yr. Records indicate that heavy rainfall on watershed greatly increases turbidity in lake water. Although some of this turbid water undoubtedly passes over spillway, much remains in lake for days after rain occurred, permitting silt to settle out. Sediment deposited in Spring Lake during its 20.4-yr. life represents avg. annual loss of 47.93 cu.ft., or 1.44 tons of sediment per acre from watershed. Anals. made of samples of sediment taken from representative parts of lake. Samples can be grouped according to definite physical and chem. characteristics. Character of sediment differs according to location in reservoir. Finer, more fertile and less compacted sediment located in main body of lake. Coarser, less fertile, more compacted and somewhat less acid deposits located in delta and impounded channel sections of lake. Lake sediment contains estd. 132,500 lb. of readily available potash, 141,000 lb. of phosphoric acid and 22,700 lb. of nitrogen. At current market prices for fertilizer, this has potential value of $21,900. Lake sediments finer textured than watershed soils, due in part at least to selective erosion and assorting effect of flowing water. Two main classifications of soils occurring in watershed: [1] dark-colored, more fertile upland prairie soils which occupy 66.3% of watershed; and [2] lighter-colored upland timber soils which make up 28.4% of watershed area. Of total cropland in watershed, 86.7% located on slopes of less than 4%. Of land in pasture, 47.1% located on slopes of less than 4%. Conservation survey shows that 82.7% of watershed is in land capability classes considered safe for continuous cultivation. At present about 97% of cultivated land falls within these capability classes. In Emmett Township, in which most of watershed lies, '38–'47 trend in cropping has been toward increasing acreages of intertilled crops—corn and soybeans. In '47 avg. farm in Emmett Township consisted of 136 acres, of which only 58% tillable. Of this tillable land, however, 63% in corn and soybeans, which denotes overproduction of these intertilled crops. Such overcropping conducive to increased soil losses. Conservation survey of watershed indicates that more than 95% of sediment in Spring Lake comes from sheet erosion. Of land area contributing to erosion, 54% now in cropland and 41% in pasture. At present small proportion of farmers of watershed partici-

(Continued on page 64)



Horton Welded Steel Reservoir

The City of Manhattan, Kan., more than doubled the storage capacity in its water system by installing the 1,250,000-gal. reservoir, shown above, in the western section of the city. It is 62 ft. in diam. and 56 ft. 6 in. to the high water line. The elevation of reservoir is about 130 ft. above the ground level at the pumping station in the southeastern portion of the city. This enables the reservoir to maintain gravity pressure in the entire system. Write our nearest office for quotations on reservoirs or elevated steel tanks.

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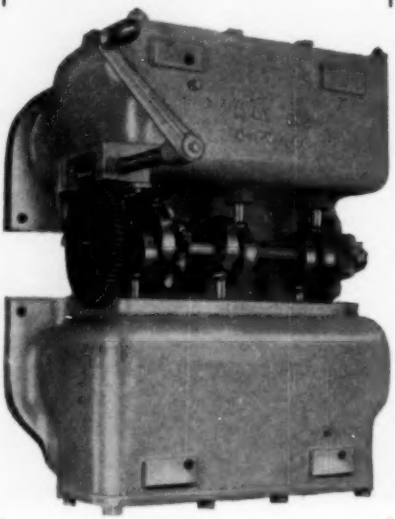

This valve, built in all sizes and for all requirements, is a masterpiece of workmanship and operating simplicity. It is available only to experienced water softener manufacturers.

Designed, built and guaranteed by

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Clayton, New Jersey

(*Continued from page 62*)

pate in soil conservation program. Great number of farms operated by tenants for absentee owners. Conservation survey shows that major changes needed in this watershed to make land use conform to land capability. In general, longer rotations needed in addn. to soil conservation measures. Estd. that complete protective program on this watershed as outlined in this report would reduce soil losses by 80%. Possible remedial measures for maintg. water supply for Macomb include: [1] raising present dam; [2] constr. of another reservoir, possibly at location just downstream from present Spring Lake; [3] adoption of intensive soil and water conservation program on watershed; and [4] development of ground water supply. Dredging does not appear economically feasible. Adoption of soil conservation practices means increased net income to farmer. For 10-yr. period, '36–'46, high-conservation farms in comparable area had net incomes (after all costs of conservation paid) of $3.46 per acre per yr. more than low-conservation farms. Recommendations: [1] qualified professional engr. should be engaged to make complete study of Macomb water supply problem; and [2] city should immediately undertake soil and water conservation program on Spring Lake watershed in cooperation wth existing conservation agencies.—*Ed.*

WELLS AND GROUND WATER

Geophysics in the Search for Water. B. J. C. O'Sullivan. Wtr. & Wtr. Eng. (Gt. Br.) **52**:214 (May '49). Elec. charting of well can give useful information regarding lithology, zones of inflow and hydrostatic pressure, not obtainable ordinarily by direct ground sample examn. As alternative to elec. logs from boreholes, and to minimize test hole drilling, depth record of ground conditions can be

(*Continued on page 66*)

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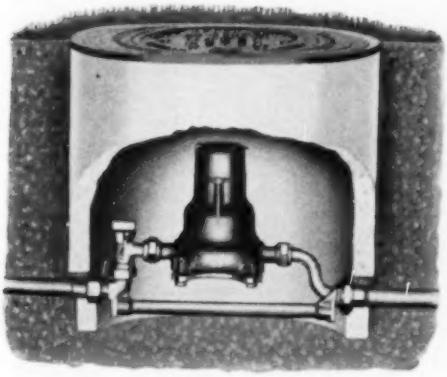

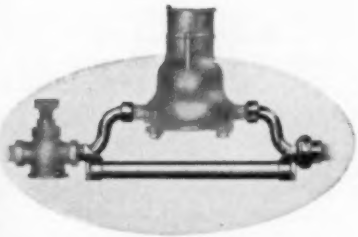

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Wabash, Indiana

(*Continued from page 64*)

obtained by resistivity methods. In "Wenner" resistivity method, 4 electrodes driven into ground, spaced equally and in line. Test current passed through ground via 2 outermost electrodes while voltage produced between inner electrodes measured to assess resistivity of ground. Rhometer instrument, when used to measure resistivity by Wenner 4-electrode arrangement, gives all field readings direct in ohm-feet apparent resistivity. Reading can be transferred from meter dial to graph sheet immediately and ground resistivity curve plotted on site. One drawback to Wenner surveying by means of 4 ground spikes, with or without const. current per foot run, was that each resistivity measurement obtained under different current density and distr. conditions within ground under test. Few, if any, resistivity measuring instruments used in England appear to meet fully elec. ground circuit conditions necessarily encountered during most resistivity measurements in field. Rhometers can be used with many different ground electrode configurations, and also to test field lines and cable winches for continuity before start of field investigation. Possible that test current can be neutralized by dc. existing in ground or by dc. induced as back emf. (polarization). To offset ground polarization, only one course seemed possible—to saturate ground with elec. current so that in effect natural potentials and electrolytic effects rendered quite small in relation to heavy test current density used and large voltage drop so caused. In bedrock contouring, problem of highly conductive overburden constantly occurs. To combat such adverse conditions, single-source electrode driven into ground over spot to be analyzed in depth. Elec. power fed to ground in pulses at this point, collected by one or more collector electrodes on large circle around source as center. If two probe electrodes, at fixed distance apart, simultaneously moved outwards and radially from source, this represents how square-law or Rhomosphere investigation carried out on surface of ground to gain information of conditions under ground. Square-law investigation consists in feeding vol. of ground with as much current as would produce const. elec. current density at point of potential measurement, if territory homogeneous. To picture this method more easily, consider current distr. from point source on surface of homogeneous conductor, such as water in large metal bowl. Here current will be radiated equally in all directions. If lump of wax introduced into water, concentric rings of potential become distorted and one can measure such distortion on surface of water. In many geophysical surveys surface variation actually being sought. In resistivity logging of wells effect of well fluid on such measurements seems ignored by those who rely on borehole elec. logs for site information. If direct comparison were possible from elec. resistivity, data would refer either to resistivity under analyzed water or obtained under certain fixed percentage satn. conditions. Strike and dip of subsurface strata bound to affect results of elec. ground measurements. Choice of geological direction or orientation of electrode lines may make or mar success of survey. Another aspect of geoelectrical surveying is effect of earth's magnetic field on all types of resistivity measurements in which electricity injected into ground at relatively low density. Geophysicist undertaking elec. measurements faced in midfield with conflicting set of requirements in area presenting appreciable geological dip. Fact that most underground test current will flow under and around horizontal line joining 2 current electrodes implies that ground surface between these power

(*Continued on page 68*)

power costs reduced 14%
volume increased 300%
coefficient raised 225%
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Before cleaning 17,000 feet of badly tuberculated 30" pipe for the City of Atlanta, a *coefficient of less than 60 was established.* After cleaning and centrilining *the coefficient was raised to over 135,* resulting in a power saving of 14% and an increase of 300% in the carrying capacity of the line.

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(*Continued from page 66*)

electrodes will be at relatively high current density. For depth surveying in area with considerable surface variations, every attempt should be made to assure: [1] that potential probes moved along line of strike, in general cases; [2] that probable path of max. current flow at surface of ground is at angle to potential electrode tracking line.—*H. E. Babbitt.*

Renovating Old Wells. F. KASSECKER. Gas, Wasser, Wärme (Austria) **2**:237 (Oct. '48). Deep wells clogged by sand, mud and corrosion products renovated by introducing ¾" water pipe and ¾" air line into casing, extending 20" below. Water under pressure introduced first, followed by air. Yield increased from 0.3 to 13.5 and 17 l./sec. Removal of sand and dirt accomplished by repeatedly forcing water into well for 10 min. and then applying suction to air line.—*W. Rudolfs.*

ANNUAL REPORTS

Greenville (S.C.) Water Works. Auditor's Report (Year Ending July 31, 1949). Operating income $596,456.96, operating expense $159,152.81, net operating profit $437,304.15, interest on bonds $84,975.79, bonds retired $158,000, addns. to permanent plant $201,570.89; excess of all expenditures over income $7,242.53, reducing current surplus to $401,080.88. Value of permanent plant $5,898,788.74, total capital assets $6,873,276.14, bonds payable $3,735,000, net bonded debt $3,404,468.60, capital surplus $3,138,276.14.—*R. E. Thompson.*

Newport News (Va.) Water Works Com. Report on Audit (1948). Current assets $726,271.18, book value of property and equip. $9,659,452.13, depreciation reserve $1,559,591.58, bonds payable $1,937,000, surplus $6,355,-

(*Continued on page 70*)

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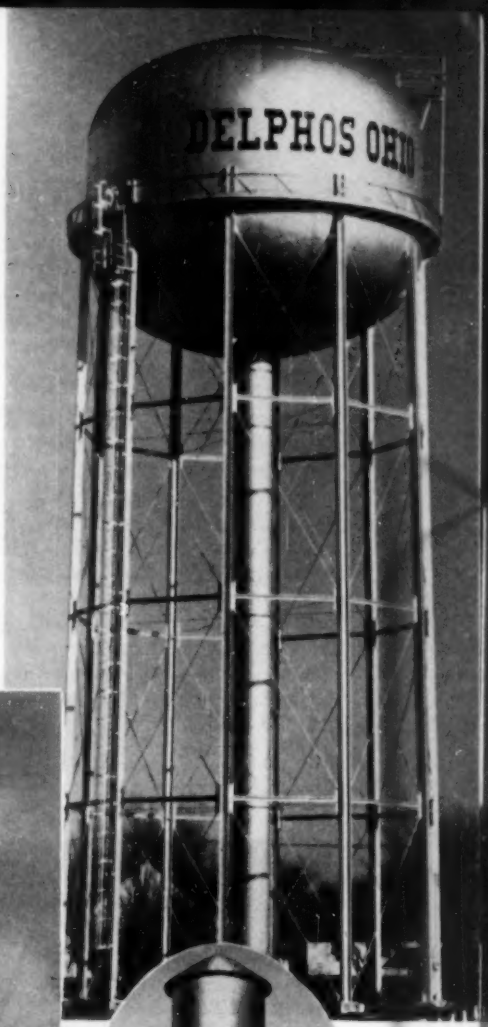

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(Continued from page 68)

245.72. Uncollectible accts. charged off $1,512.09. Total water sales $935,-177.16, operating income $957,204.03, operating expense $576,994.94, profit from operation $380,209.09, net income $331,251.91, bonds retired $83,000, bonds payable $1,937,000.—*R. E. Thompson.*

Richmond (Va.) Dept. of Public Utilities. Annual Report (Year Ending June 30, 1949). Pop. 240,400, water customers 52,826 (128.6 gpd./cap.), customers per mi. of main 97, earnings per person $8.47. 2 settling basins, each of 85 mil.gal. capac.; 10 filters with 10,780 sq.ft. area, rated capac. 30 mgd. but operated successfully at 35; finished-water storage 2.5 mil.gal., addnl. finished water available 6.4 mil.gal.; elevated storage 2.1 mil. gal. (3 tanks). Avg. water treated 31.9 mgd., avg. filter run 71.2 hr. Activated C applied to filters at beginning of run, addnl. amts. added at intervals of 24 hr. If more than 10 lb./mil.gal. required, excess added before coagulant. Chem. treatment before filtration: $CuSO_4$, Cl 22.6 lb./mil.gal. avg., CaO (intermittent), alum, chlorinated copperas, activated C 5.5 lb./mil.gal. avg.; after filtration: NH_3 3.2, Cl 11.5, CaO 54.7 lb./mil.gal. avg. Avg. turbidity reduced from 36 to 0.11, color from 59 to 2.1, alky. from 39 to 29, O consumed from 5.7 to 1.8 ppm. Max. turbidity of raw and filtered water 350 and 0.5, respectively, color 280 and 8. Avg. pH increased from 7.5 to 8.7. Avg. bact. count (37°C.) reduced from 1,271 to 0 per ml. No positive presumptive coliform tests on finished water in 100, 10 or 1 ml. Mi. of mains 544, fire hydrants 3,276, active meters

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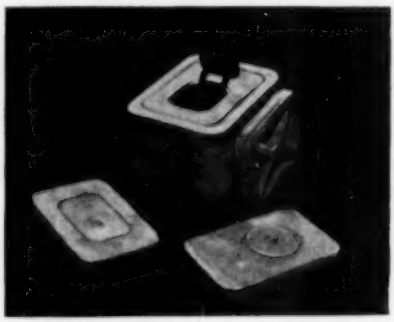

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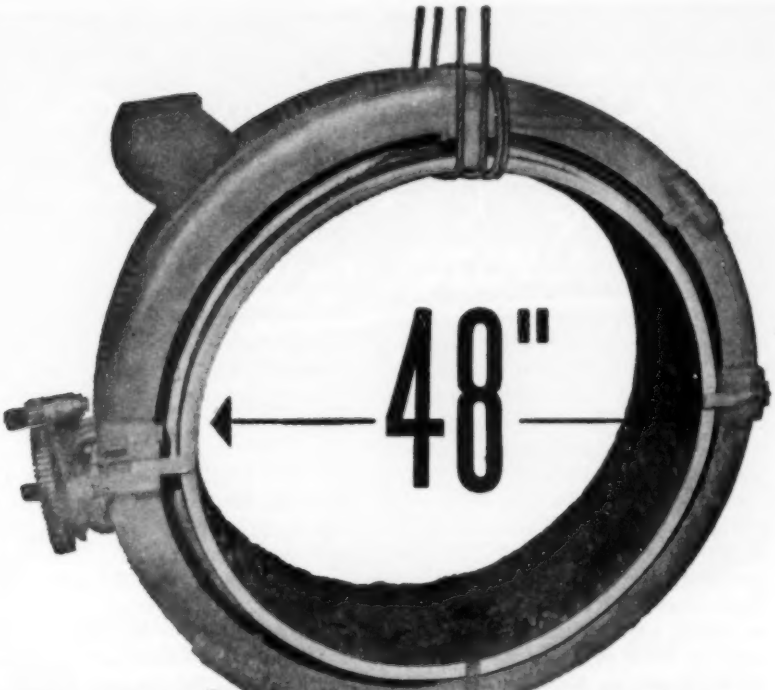

removed under pressure

This pipe section was cut, under pressure, from a 48″ main without shut-down or other interruption to service. The operation was performed in the course of inserting a gate valve in a 48″ cast iron main, in the distribution system of the Water Bureau, City of Philadelphia, Pa.

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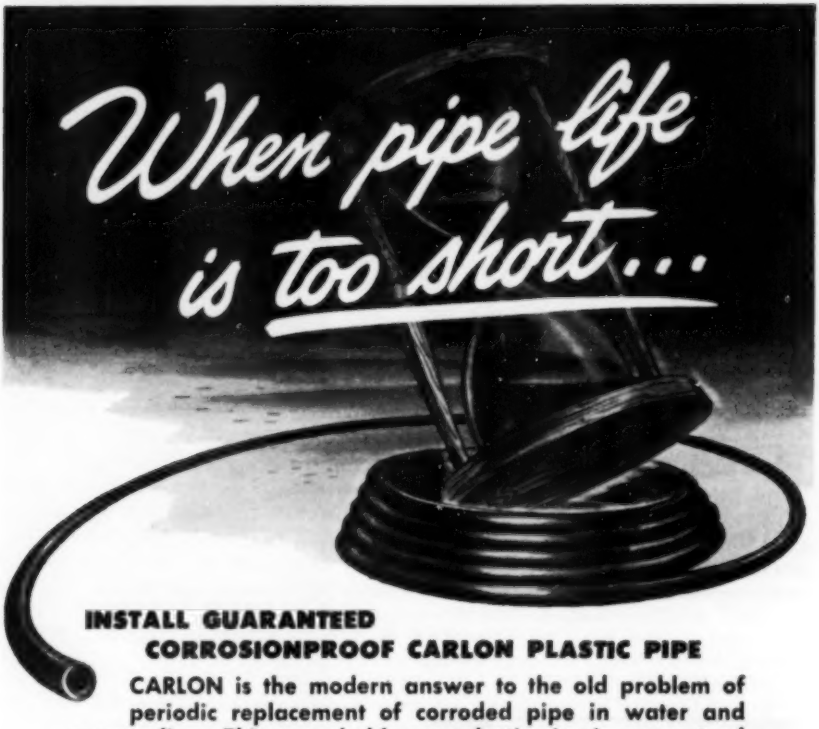
(*Continued from page 70*)

53,920. Rates: first 600 cu.ft. or less per mo. $1.00, balance 6–15¢ per 100 cu.ft., in county 6.5–32.5¢ per 100 cu.ft.—*R. E. Thompson.*

Tacoma (Wash.) Dept. of Public Utilities. Report of Water Div. (1948). Plant investment increased from $1,125,000 when purchased in 1893 to $17,289,770.36; capac. increased from 6 to 70 mgd. from Green R. gravity system. 39 mgd. from auxiliary well system will be increased to more than 63 mgd. by wells under constr. System self-supporting with no increase in rates for general use since '19. Green R. watershed on west slope of Cascade Mts., heavily wooded and mountainous, rises from el. 895 at diversion dam to over el. 5,700. Pptn. probably exceeds 85″ per yr. Water flows from dam through short tunnel to settling basin, thence mainly in concrete or steel pipeline, 39–64″ diam., about 27 mi. to McMillin Res. (110 mil.gal.). Two pipelines, one 15 mi. long, connect latter to city distr. system, water being admitted through automatic reducing valves at key points in higher service. Water can be drawn from McMillin Res. at rate of 93 mgd. Green R. water normally requires no clarification, but when turbid due to floods, city supplied from storage and wells. Hardness of river water 21 and of well water 61 ppm. Cl and NH_3, in 10:1 ratio, applied ½ mi. below intake and again at outlet of McMillin Res. Well water normally sterile but also treated with Cl. About 1500 samples from distr. system examd. annually for Cl and bact. qual. Distr. mains 394 mi., gates 6532, hydrants 2119, standpipes 5 (2.5 mil.gal. total capac.), distr. storage 49 mil.gal. pumping station capac. 28,350 gpm. McMillin Res. water not used by high service is spilled to middle-service reservoir, surplus from latter to low-service reservoir, and from latter to bay. 38,808 services, 13,768 metered. Pop. served 151,000, 12,000 outside city. Avg. consumption exclusive of pulp mills 33.36 mgd. (221 gpd./cap.), avg. total consumption 50.43 mgd., max. 70.3. Avg. cost of water delivered 4.2¢ per 100 cu.ft., of which 0.39¢ fixed charges. Gross revenue $1,256,989.69, net income $252,600.66, bonds redeemed $411,000, surplus $6,351,833.07, bonds outstanding $4,077,000. Metered rates 4–10¢ per 100 cu.ft., plus ready-to-serve charge of 50¢ per mo. (¾″ meter) up.—*R. E. Thompson.*

Halifax (N.S.) Public Service Com. Annual Report (1948). Area 6.84 sq.mi., pptn. 66.6″, estd. pop. 98,719, pop. per mi. mains 907. Total natural reservoir surface 992 acres, total watershed 10,155 acres, mains from lakes to city limits 10.4 mi., mains inside limits 108.9; total storage capac.—high service 700 mil.gal., low service 1773 mil.gal.; total water supplied 4128 mil.gal. Gross value of utility plant $6,865,528.84, provision for depreciation $1,854,630.77. Operating revenue $776,662.25, operating expense $391,264.12, depreciation $90,000, debt service charges $233,018.02, surplus $24,289.50. **General Manager's Report:** New rate schedule in effect 9 mo.—deficit of about $115,000 in '47 changed to surplus as above. Cooperation with fire dept. and maint. of services at high std. secured reduced insurance rates. Adoption of "Willing Water" for public relations material achieved most encouraging results. With view to improving understanding of management problems by employees, arrangements made for 2 of latter to attend executive meetings. Safety program: time lost through accidents 812 hr. compared to 2128 in '47. **Office Manager's Report:** Consumers 13,456, increase of 200. Largely quar-

(*Continued on page 74*)



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STD. SIZE	O. D.	I. D.	CALCULATED B. P. P. S. I.	WT./FT.	NORMAL SHIPPING LENGTHS
1/2"	0.840	0.622	540 lb.	0.103 lb.	400 ft. coils
3/4"	1.050	0.824	350 lb.	0.140 lb.	400 ft. coils
1"	1.310	1.070	200 lb.	0.181 lb.	300 ft. coils
1 1/4"	1.660	1.380	200 lb.	0.267 lb.	300 ft. coils
1 1/2"	1.900	1.610	200 lb.	0.320 lb.	250 ft. coils
2"	2.378	2.070	170 lb.	0.445 lb.	200 ft. coils
3"	3.504	3.070	165 lb.	0.91 lb.	100 ft. coils
4"	4.504	4.030	150 lb.	1.25 lb.	25 ft. str.
6"	6.630	6.070	115 lb.	2.23 lb.	25 ft. str.

CARLON CP

CARTER PRODUCTS CORPORATION
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CLEVELAND 5, OHIO

(Continued from page 72)

terly billing, investigator contacts all delinquents. Service suspended for only 6 accounts and uncollectible accts. total only $345.22, i.e., less than 0.06% of revenue from water sales. Approx. 37% of accts.—nearly double that in '47—paid at collecting banks. Stub billing substituted for ledger card system and found very satisfactory. Total of 114,995 meter readings made by staff of 7—less than 1% obtained by postcard and second calls. Perpetual plant inventory nearly complete. Capital funds borrowed from bank as required and liquidated at end of yr. by debentures. Leakage survey, cost $8333, corrected loss of 1.8 mgd. Detailed financial statistics presented and explained. Net surplus to Dec. 31, '48, $263,179.93. **Chief Engineer's Report:** Expts. made on treatment of super-high-service water at Robie St. Pumping Station with about 12 ppm. Na silicate to correct corrosiveness. Sample nipples of Pb, Fe, Cu and brass placed in treated and untreated water lines. No apparent difference in coating on these in 2 mo. Expt. being continued. Leakage resurvey (surveyed in '46) revealed leakage totaling about 16% of consumption. Saving nearly 3 times cost of survey. Watershed patrolled regularly; contamn. of raw water considerably less. Avg. Cl dosage about 1 ppm. Closer control over residual Cl through use of OTA comparator. Transmission mains, 15 and 20″, cleaned at cost of 4.5¢/ft. Scraper stuck at one point had to be removed by excavation. All hydrants repainted and numbered at cost of 99¢ ea. System of detailed hydrant records inaugurated. Services thawed with elec. arc-welder (204) and hot

(Continued on page 76)

There is a plus value in Kupferle Fire Hydrants. The Know How acquired through fifty years of continuous production.

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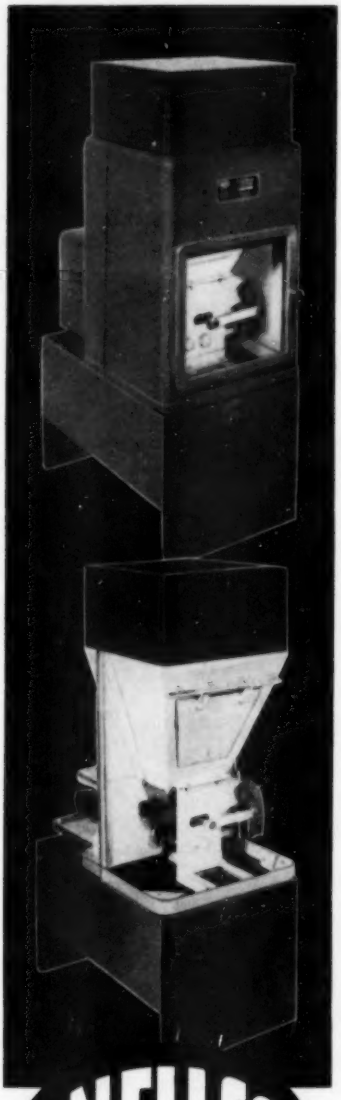

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(Continued from page 74)

water tube (16). Time for former 2–4 min. Meters tested periodically and changed every 5 yr. Hydrants 768, main valves 1551, meters 13,456. Avg. consumption 11.28 mgd. pH 4.5–6.5.—*R. E. Thompson.*

Singapore Water Dept. Annual Report (1948). Difficulties in securing adequate supplies and staff, together with terrorist activities, interfered with catchment area inspection. Sedimentation insufficient and plant at Johore obsolete but reasonable results obtained. All raw waters treated with lime at source and later with ammonia and Cl. New meters and waste detection increased accounted-for water from 85.1 to 90.9%. Safe capac. of works 29 mgd.; avg. daily consumption 31.36, of which 0.38 salt water. Avg. cost per 1000 gal. 53¢, salt water 25¢. Rainfall at 3 impounding reservoirs on island and 3 at Johore 107.5–139.5″. At Woodleigh slow sand filters, treatment with lime and soda ash before sedimentation, and with lime, ammonium sulfate and Cl after filtration, avg. dosage of latter 0.58 ppm. Avg. filter run 21 days, avg. rate of filtration 416 gal./sq.yd./day. At Bukit Timah mech. filters, treatment with lime and Cl before sedimentation and with Cl, ammonium sulfate and ammonium chloride after filtration. Avg. Cl dosages 0.47 and 0.6 ppm., respectively. Avg. per filter run 8167 gal./sq.ft. At Gulong Pulai filters, treatment with lime, soda ash, alum, NH_3 and Cl before filtration and with Cl and ammonium sulfate after filtration. Avg. Cl dosages at various points 0.24–0.38 ppm. Amount per filter run 1602 gal./sq.ft., wash water 10.13% of water filtered. Avg. anal. of tap water: alky. 13.3 ppm., pH 7.6, free Cl 0.013 ppm., agar count 87, lactose fermenters absent in 100 ml. in 95.6% of samples. Distr. mains 432 mi., supply mains 74 mi., hydrants 3801. Waste survey on 371 mi. of mains saved estd. 0.52 mgd.—*R. E. Thompson.*

OTHER ARTICLES NOTED

Recent articles of interest, appearing in American periodicals not abstracted, are listed below.

Radioactive Tracers in Flow Tests. RALPH S. ARCHIBALD. J. Boston Soc. Civ. Engrs., **37**:1:49 (Jan. '50).

Cavitation in Centrifugal Pumps. A. J. STEPANOFF. Eng. Papers of Hydraulic Inst., **2**:5 ('50).

A Comparative Study of Media for the Detection of Streptococci in Water and Sewage. W. L. MALLMANN & E. B. SELIGMANN JR. Am. J. Pub. Health, **40**:286 (March '50).

Effects of DDT Mosquito Larviciding on Wildlife. V. Effects on Fishes. . . . CLARENCE M. TARZWELL. Pub. Health Repts., **65**:231 (Feb. 24, '50).

Engineers Build 500-mgd. Water System for Sunbury Steam-Electric Station. CHARLES B. SEIB. Civ. Eng., **20**:2:26 (Feb. '50).

The Design and Construction of Perry Barr Service Reservoir. C. A. RISBRIDGER. Jour. N.E.W.W.A., **63**:4:325 (Dec. '49).

Chicago Area Water Supply—A Symposium. Midwest Engr., **2**:6:6 (Feb. '50).

Casual Observations of English Water Works Practice. E. SHERMAN CHASE. Jour. N.E.W.W.A., **63**:4:315 (Dec. '49).

Important 1949 Court Decisions. LEO T. PARKER. W.W. Eng., **103**:2:125 (Feb. '50).

CONSIDER THESE ADVANTAGES OF AMERICAN CONCRETE CYLINDER PIPE

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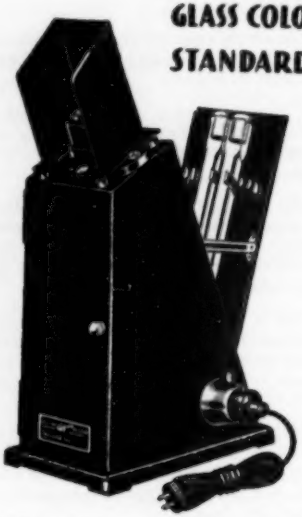

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Service Lines

A "Chlorine Handbook" containing general information on chlorine, its characteristics, hazards and history, as well as technical information and charts showing its properties, has been prepared and is available from Diamond Alkali Co., 300 Union Commerce Bldg., Cleveland 14, Ohio. The booklet is handsomely printed and illustrated and contains 44 pages.

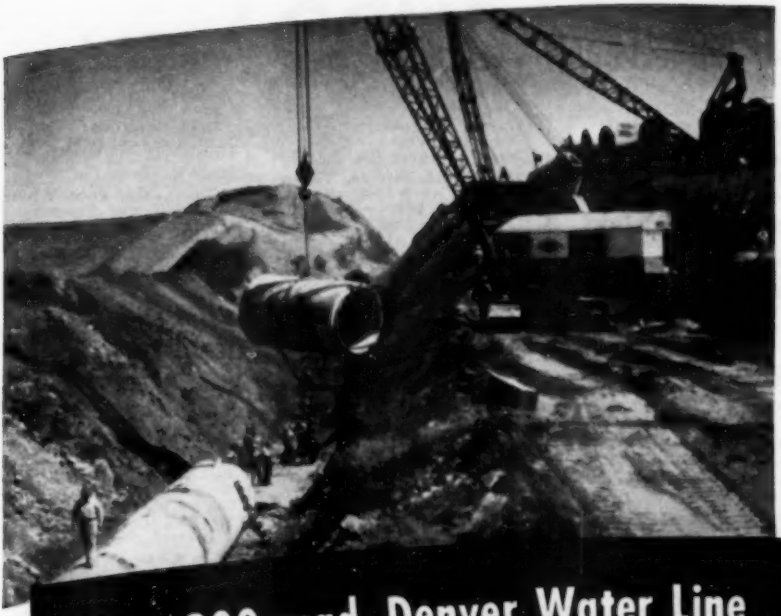
Rex travelling water screens are the subject of Bul. 50-36 issued by Chain Belt Co., 1600 W. Bruce St., Milwaukee, Wis. Information essential to the selection of the proper screen for any given application is included in the 12-page, illustrated booklet.

Low-speed synchronous motors for high power factor, constant-speed drives are the subject of a new bulletin, No. GEA-5332, available from the General Electric Co., Schenectady 5, N. Y.

A circular illustrating power operation of gates and gate valves is obtainable from Payne Dean & Co., Madison, Conn.

A folder on Hills-McCanna diaphragm valves, Bul. V-50A, is available from the company at 3025 N. Western Ave., Chicago 18, Ill. Cutaway illustrations and diagrams show the construction of the valve, which utilizes the Saunders patent principle.

The products, services and background of Graver Water Conditioning Co. are outlined in an 8-page brochure, Bulletin WC–100, which is available from Dept. 110 of the company at 216 W. 14th St., New York 11.



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(See Prof. Services, pp. 24–27)

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Dowell Incorporated

Manometers, Rate of Flow:
Builders-Providence, Inc.

Meter Boxes:
Art Concrete Works
Ford Meter Box Co.
Pittsburgh Equitable Meter Div.

Meter Couplings and Yokes:
Badger Meter Mfg. Co.
Dresser Mfg. Div.
Ford Meter Box Co.
Hays Mfg. Co.
Hersey Mfg. Co.
James Jones Co.
Mueller Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
A. P. Smith Mfg. Co.
Worthington-Gamon Meter Co.

Meter Reading and Record Books:
Badger Meter Mfg. Co.

Meter Testers:
Badger Meter Mfg. Co.
Ford Meter Box Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.

Meters, Domestic:
Badger Meter Mfg. Co.
Buffalo Meter Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
A. P. Smith Mfg. Co.
Well Machinery & Supply Co.
Worthington-Gamon Meter Co.

Meters, Filtration Plant, Pumping Station, Transmission Line:
Builders-Providence, Inc.
Infilco, Inc.
Simplex Valve & Meter Co.
R. W. Sparling

Meters, Industrial, Commercial:
Badger Meter Mfg. Co.
Buffalo Meter Co.
Builders-Providence, Inc.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Simplex Valve & Meter Co.
A. P. Smith Mfg. Co.
R. W. Sparling
Well Machinery & Supply Co.
Worthington-Gamon Meter Co.

Mixing Equipment:
Belco Industrial Equipment Div., Inc.
Chain Belt Co.
Infilco, Inc.
Walker Process Equipment, Inc.

Ozonation Equipment:
Welsbach Corp., Ozone Processes Div.

Pipe, Asbestos-Cement:
Johns-Manville Corp.
Keasbey & Mattison Co.

Pipe, Brass:
American Brass Co.

Pipe, Cast Iron (and Fittings):
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
Central Foundry Co.
James B. Clow & Sons
United States Pipe & Foundry Co.
Warren Foundry & Pipe Corp.
R. D. Wood Co.

Pipe, Cement Lined:
Cast Iron Pipe Research Assn.
Central Foundry Co.
James B. Clow & Sons
United States Pipe & Foundry Co.
Warren Foundry & Pipe Corp.
R. D. Wood Co.

Pipe Coatings and Linings:
The Barrett Div.
Cast Iron Pipe Research Assn.
Centriline Corp.
Koppers Co., Inc.
Reilly Tar & Chemical Co.
Warren Foundry & Pipe Corp.

Pipe, Concrete:
American Pipe & Construction Co.
Lock Joint Pipe Co.

Pipe, Copper:
American Brass Co.

Pipe Cutting Machines:
Ellis & Ford Mfg. Co.
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Pipe Jointing Materials:
(See Jointing Materials)

Pipe Locators:
Goldak Co.
Jos. G. Pollard Co., Inc.

Pipe, Plastic:
Carter Products Corp.

Pipe, Steel:
Armco Drainage & Metal Products, Inc.
Bethlehem Steel Co.

Pipelines, Submerged:
Boyce Co., Inc.

Plugs, Removable:
James B. Clow & Sons
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.
Warren Foundry & Pipe Corp.

Potentiometers:
Hellige, Inc.

Pressure Regulators:
Ross Valve Mfg. Co.

Pumps, Boiler Feed:
DeLaval Steam Turbine Co.
Fairbanks, Morse & Co.
Peerless Pump Div., Food Machinery Corp.

Pumps, Centrifugal:
American Well Works
DeLaval Steam Turbine Co.
Economy Pumps, Inc.
Fairbanks, Morse & Co.
Peerless Pump Div., Food Machinery Corp.

Pumps, Chemical Feed:
Infilco, Inc.
Proportioneers, Inc.
Wallace & Tiernan Co., Inc.

Pumps, Deep Well:
American Well Works
Fairbanks, Morse & Co.
Layne & Bowler, Inc.
Peerless Pump Div., Food Machinery Corp.
Worthington Pump & Mach. Corp.

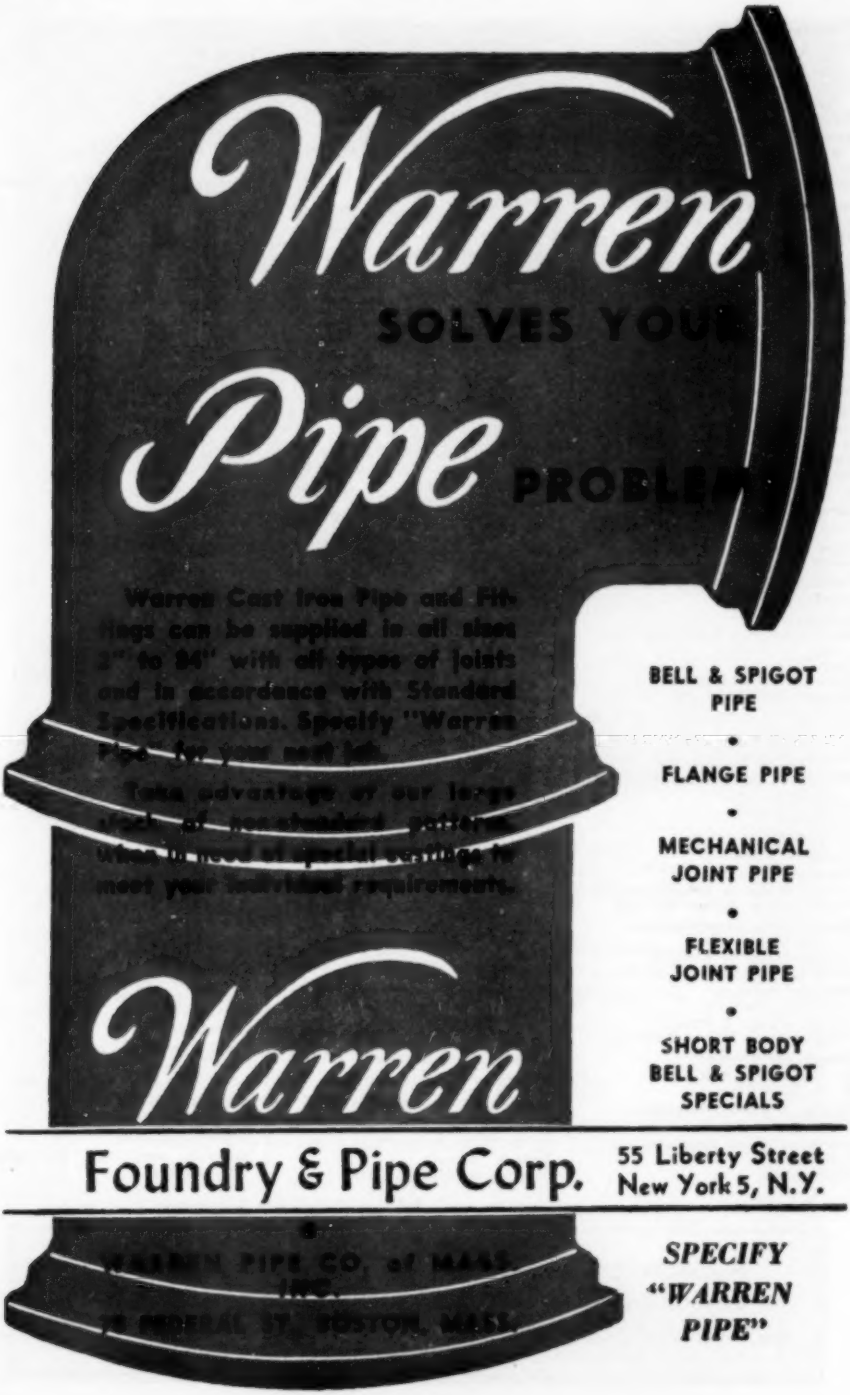
Pumps, Diaphragm:
Dorr Co.
Proportioneers, Inc.

Pumps, Hydrant:
Jos. G. Pollard Co., Inc.

Pumps, Hydraulic Booster:
Fairbanks, Morse & Co.
Ross Valve Mfg. Co.

Pumps, Sewage:
DeLaval Steam Turbine Co.
Economy Pumps, Inc.
Fairbanks, Morse & Co.
Peerless Pump Div., Food Machinery Corp.

Pumps, Sump:
DeLaval Steam Turbine Co.
Economy Pumps, Inc.
Fairbanks, Morse & Co.
Peerless Pump Div., Food Machinery Corp.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Fairbanks, Morse & Co.
Layne & Bowler, Inc.
Peerless Pump Div., Food Machinery Corp.
Worthington Pump & Mach. Corp.

Recorders, Gas Density CO_2, NH_3, SO_2, etc.:
Permutit Co.
Wallace & Tiernan Co., Inc.

Recording Instruments:
Builders-Providence, Inc.
Infilco, Inc.
R. W. Sparling
Wallace & Tiernan Co., Inc.

Reservoirs, Steel:
Chicago Bridge & Iron Co.
Pittsburgh-Des Moines Steel Co.

Sand Expansion Gages:
(See Gages)

Sleeves:
(See Clamps)

Sleeves and Valves, Tapping:
James B. Clow & Sons
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.

Sludge Blanket Equipment:
Permutit Co.

Soda Ash:
Solvay Sales Div.

Sodium Hexametaphosphate:
Calgon, Inc.

Softeners:
Belco Industrial Equipment Div., Inc.
Dorr Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco, Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Softening Chemicals and Compounds:
Calgon, Inc.
Infilco, Inc.
Permutit Co.
Tennessee Corp.

Standpipes, Steel:
Chicago Bridge & Iron Co.
Pittsburgh-Des Moines Steel Co.

Steel Plate Construction:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Pittsburgh-Des Moines Steel Co.

Storage Tanks:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Pittsburgh-Des Moines Steel Co.

Strainers, Suction:
M. Greenberg's Sons
R. D. Wood Co.

Sulfur Dioxide, Liquid:
Virginia Smelting Co.

Surface Wash Equipment:
Permutit Co.
Stuart Corp.

Swimming Pool Sterilization:
Belco Industrial Equipment Div., Inc.
Everson Mfg. Corp.
Omega Machine Co. (Div., Builders Iron Fdry.)
Proportioneers, Inc.
Wallace & Tiernan Co., Inc.
Welsbach Corp., Ozone Processes Div.

Tanks, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Pittsburgh-Des Moines Steel Co.

Tapping Machines:
Hays Mfg. Co.
Mueller Co.
A. P. Smith Mfg. Co.

Taste and Odor Removal:
Industrial Chemical Sales Div.
Infilco, Inc.
Proportioneers, Inc.
Walker Process Equipment, Inc.
Wallace & Tiernan Co., Inc.
Welsbach Corp., Ozone Processes Div.

Telemeters, Level, Pump Control, Rate of Flow, Gate Position, etc.:
Builders-Providence, Inc.

Turbidimetric Apparatus (For Turbidity and Sulfate Determinations):
Hellige, Inc.
Wallace & Tiernan Co., Inc.

Turbines, Steam:
DeLaval Steam Turbine Co.

Turbines, Water:
DeLaval Steam Turbine Co.

Valve Boxes:
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James B. Clow & Sons
Ford Meter Box Co.
M & H Valve & Fittings Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valve Inserting Machines:
A. P. Smith Mfg. Co.

Valves, Altitude:
Ross Valve Mfg. Co., Inc.

Valves, Butterfly, Check, Flap, Foot, Hose, Mud and Plug:
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M. Greenberg's Sons
M & H Valve & Fittings Co.
Rensselaer Valve Co.
R. D. Wood Co.

Valves, Detector Check:
Hersey Mfg. Co.

Valves, Electrically Operated:
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Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Philadelphia Gear Works, Inc.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.

Valves, Float:
Ross Valve Mfg. Co., Inc.

Valves, Gate:
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James Jones Co.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Hydraulically Operated:
James B. Clow & Sons
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Philadelphia Gear Works, Inc.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Large Diameter:
James B. Clow & Sons
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co.
M & H Valve & Fittings Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Regulating:
Ross Valve Mfg. Co.

Valves, Swing Check:
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Rensselaer Valve Co.
A. P. Smith Mfg. Co.
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Waterproofing
Inertol Co., Inc.

Water Softening Plants:
(See Softeners)

Water Supply Contractors:
Layne & Bowler, Inc.

Water Testing Apparatus:
Hellige, Inc.
LaMotte Chemical Products Co.
Photovolt Corp.
Wallace & Tiernan Co., Inc.

Water Treatment Plants:
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Chain Belt Co.
Chicago Bridge & Iron Co.
Dorr Co.
Everson Mfg. Corp.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco, Inc.
Pittsburgh-Des Moines Steel Co.
Roberts Filter Mfg. Co.
Stuart Corp.
Walker Process Equipment, Inc.
Wallace & Tiernan Co., Inc.
Welsbach Corp., Ozone Processes Div.

Well Acidizing:
Dowell Incorporated

Well Drilling Contractors:
Layne & Bowler, Inc.

Wrenches, Ratchet:
Dresser Mfg. Div.

Zeolite; see: Ion Exchange Materials

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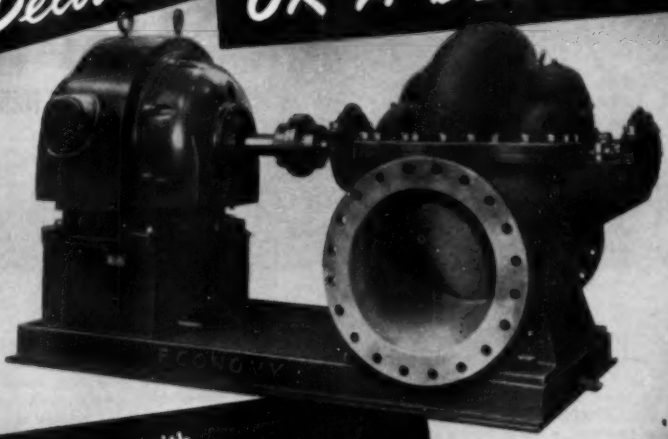

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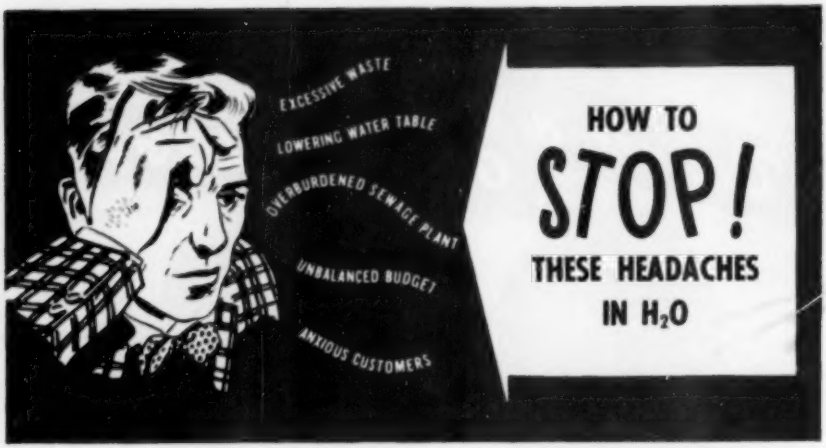

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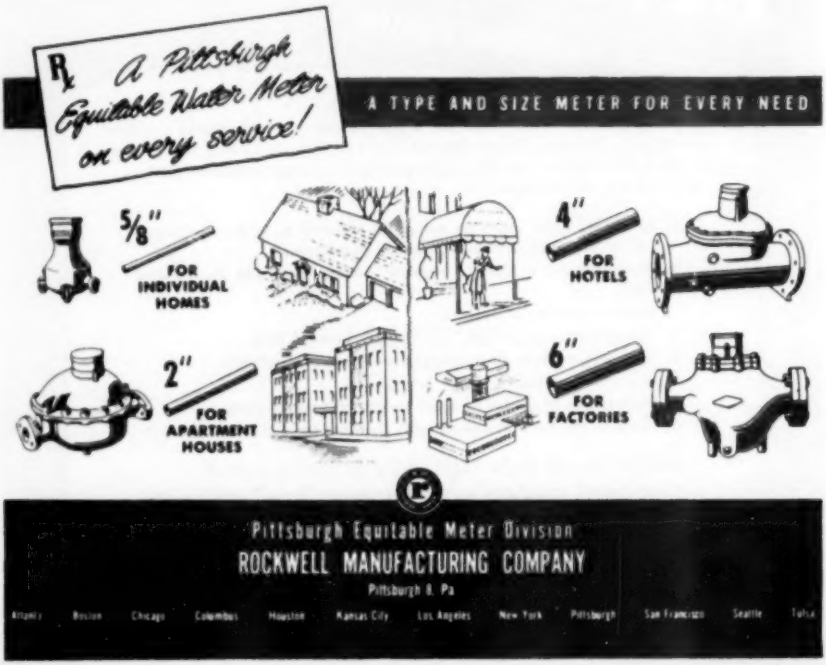
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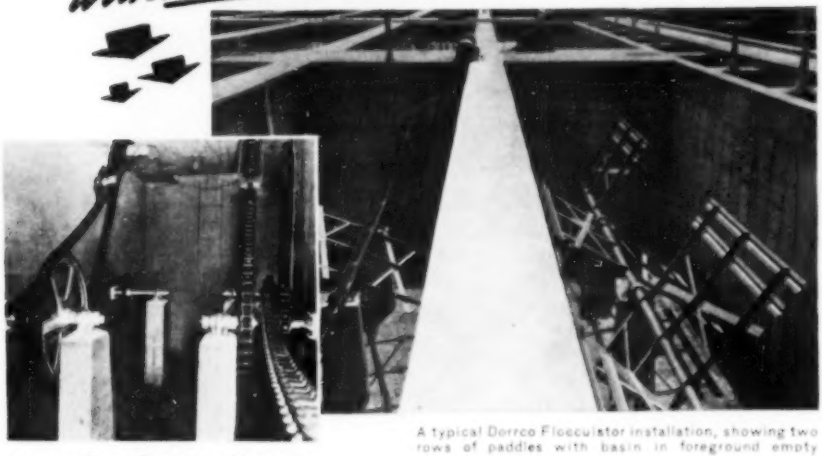

Closeup of Dorrco Flocculator drive mechanism showing completely enclosed dry well

A typical Dorrco Flocculator installation, showing two rows of paddles with basin in foreground empty

That's the actual case history of a Dorrco Flocculator installation at a large Eastern water treatment plant. The water works superintendent reports absolutely no trouble with bearings, paddles, or drive mechanism since this unit was first installed in 1939 at a design capacity of 10 M.G.D. This is typical of the operating dependability you get with Dorrco Flocculators. The dry well feature means that the entire drive mechanism is never exposed to water and is readily accessible at all times.

If you have existing plain basins, chances are they can be converted easily—and at a substantial saving in cost. New plant or modernization, Dorrco Floculators will improve your entire pre-treatment operation. A close check on one installation after only three months of operations showed:

- **Filter runs lengthened 40%.**
- **Wash water demands reduced 30%.**
- **Alum costs cut 30%.**

Why not write for further information concerning the savings and increased efficiency that Dorrco Flocculators can achieve in your plant?

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An important optional design feature of the Dorrco Flocculator is the Automatic Lubricator for submerged bearings. Actuated by the shaft rotation, it contains over a year's supply of grease and insures trouble-free bearing operation at all times.

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